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An International Journal

Official Organ of the
American Phytopathological Society

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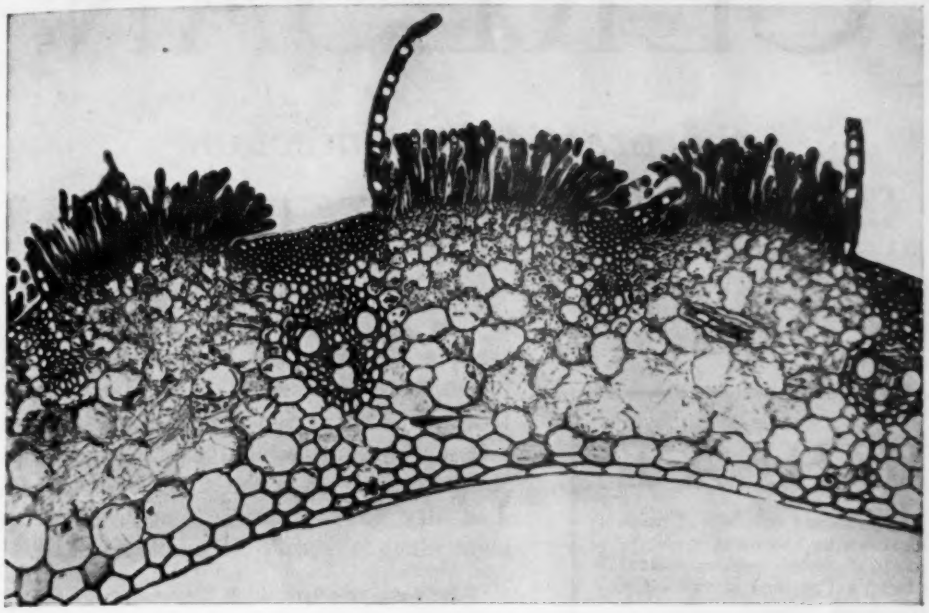

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RALPH CLEON THOMAS

PHYTOPATHOLOGY

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DECEMBER, 1929

RALPH CLEON THOMAS

1892–1928

S. A. WINGARD

Ralph Cleon Thomas was born at Grant, Grayson County, Virginia, April 9, 1892, and died at Tifton, Georgia, December 25, 1928. He was reared on a Grayson County farm and received his elementary education in the public schools of the neighborhood, graduating from the Bridle Creek High School, Bridle Creek, Virginia, in June, 1912.

Early in life he developed a love for the sciences, especially for botany. With his favorite science uppermost in mind he entered the Virginia Polytechnic Institute in 1913 and was graduated in June, 1917, receiving the B. S. degree in Agriculture. He was immediately appointed Student Assistant in the Department of Bacteriology and Plant Pathology of his Alma Mater. In this capacity he rendered proficient service and at the same time pursued graduate work in plant pathology until February 28, 1918, when he enlisted in the Medical Corps of the United States Army. He served in the bacteriological laboratory at Camp Lee, Virginia, until July, when he sailed with his unit to France. He served overseas until May, 1919.

Upon his return from Europe he received his discharge from the Army and resumed his graduate studies at the Virginia Polytechnic Institute and received the M. S. degree in plant pathology in July, 1919. He was immediately appointed Assistant County Agent in the Virginia Agricultural Extension Division to make a special survey of the nematode disease of wheat. He was appointed Plant Pathologist of the Virginia Agricultural Extension Division in November, 1919, in which capacity he served until September 1, 1922, working chiefly on cereal and tobacco diseases. Feeling the need of further training he went to Michigan State College as Graduate Assistant in Bacteriology and did special cultural and diagnostic work until August, 1923. He taught in the Jackson High School, Roanoke, Virginia, during the session of 1923–1924.

Being desirous of returning to research, his first love, he studied at Cornell University during the summer session of 1924. On October 15, 1924, he was appointed Assistant Plant Pathologist in the Office of To-

bacco Investigations, Bureau of Plant Industry, United States Department of Agriculture, and stationed at the Coastal Plains Experiment Station, Tifton, Georgia, where he conducted laboratory and field investigations on tobacco disease in the Southern States, more particularly in the new tobacco district of southern Georgia. This work dealt primarily with the development of methods of control for nematodes, black shank, wild fire, black fire, and other tobacco diseases of importance in the South. He was engaged in this work at the time of his untimely death.

My acquaintance with Mr. Thomas began in the fall of 1917 when I was employed by the Virginia Agricultural Experiment Station. We became intimate friends, roomed together for several years, and were closely associated in both work and play until the time of his death. I have never known a man who was more conscientious in the performance of his duties and more loyal and sincere to his friends than he. The genuineness of his of his friendship was indicative of his noble character. Among God's noblemen none ever was more merciful to his opponents; none more thoughtful of the unfortunate and neglected. He was a veritable incarnation of Christianity, and though taken in the flower of young manhood, Ralph Cleon Thomas will always be alive in the memory of his friends.

A STUDY OF THE BIOLOGY OF A NEW SPORE-FORMING RHIZOCTONIA, CORTICIUM PRATICOLA[1]

JOHN E. KOTILA[2]

INTRODUCTION

The fungi of the form-genus Rhizoctonia are among the most common and universally distributed groups of pathogenic soil fungi and have been studied by a great many investigators. As a result, much difference of opinion has arisen as to whether numerous species exist, each associated with certain hosts, or whether there are just a few main species, each of which may contain numerous forms or strains.

Matz (54) believes that there are a great many species and differentiates them by vegetative characters. Duggar (28) and Peltier (62), on the other hand, prefer to consider Rhizoctonia as composed of two main species, *Rhizoctonia solani* Kühn (*Corticium vagum* B. & C.) and *Rhizoctonia crocorum* (Pers.) DC. Briton-Jones (9), in his study of Rhizoctonia, found that differences occurred when a single strain was grown under different conditions and that, in his opinion, these differences were sufficiently marked to warrant separation of such a strain into distinct species, provided the Matz (54) method of differentiation be used. This investigator found macroscopic differences between such strains in culture but the microscopic differences were so slight that he did not think a multiplication of "species" justifiable on such grounds. He retained the name *Corticium vagum* (*Rhizoctonia solani*) for the forms or strains with which he worked, realizing, however, that the species contains several physiologic forms or strains. Gratz (34), Jochems (37), Matsumoto (53), Raeder, Hungerford, and Chapman (65), Thomas (79), and van der Meer (55) have reported strain differences in culture of *R. solani*. Thomas (79) studied 20 different cultures, obtained from various sources, and concluded from his examination of vegetative characters that all of them belonged to one botanical species, *R. solani*. He adds, however, that until it is possible to obtain in culture the basidiospore stage of the various strains, it will not be possible to classify them systematically.

It is common experience that *R. solani* remains sterile when grown on artificial media under ordinary laboratory conditions, while, in nature, the perfect stage of the fungus is formed more or less freely on a wide range

[1] Papers from the Department of Botany of the University of Michigan, No. 313.

[2] The author acknowledges his great indebtedness to Professor C. H. Kauffman, of the University of Michigan, under whose direction the present investigation has been conducted, and to Dr. E. A. Bessey and Dr. G. H. Coons, of the Michigan State College, for helpful suggestions and advice.

of hosts. Very little is known of the factors involved in the formation of basidiospores of *R. solani* and the lack of such knowledge has retarded the clearing up of the Rhizoctonia situation.

In 1924 the writer undertook an investigation to determine whether strains of *R. solani* and *R. crocorum*, such as those referred to above, have any significance. Cultures of Rhizoctonia were received from plant pathologists in various parts of the United States. Most of these cultures unquestionably belonged to the *R. solani* group. The *R. crocorum* group was not represented. A number of pure cultures of the latter were obtained, however, in October, 1924, while making a study of the violet root rot of alfalfa in Michigan. Two additional cultures of *R. crocorum* were received later from England through the courtesy of Buddin and Wakefield (11). All of these cultures formed the reddish brown or magenta colored mycelium characteristic of *R. crocorum*. At the same time a species of Rhizoctonia, apparently different from *R. solani* and *R. crocorum*, was isolated from a mass of hyphae and spores present on one of the diseased alfalfa plants. Several weeks later it was observed that this Rhizoctonia had produced its hymenial stage in pure culture (47). In view of the lack of information concerning the factors involved in spore formation in the Rhizoctonias and of the opportunity afforded by the new species to study this problem, it seemed advisable to undertake an intensive study of this new species.

The present investigation was begun and continued at the University of Michigan during the academic year, 1924–25, and has been continued at the Michigan State College up to the present time (1928).

HISTORICAL[3]

The first report of a plant disease caused by a species of Rhizoctonia was made by Duhamel (30) in 1728. His description of the symptoms indicates that the fungus concerned was *Rhizoctonia crocorum*. Although considered under different names, this fungus appears to have been the only form reported by investigators previous to 1858, when Kühn (48) described a different one, pathogenic on potato, and readily distinguishable from *R. crocorum*. Kühn named the new species *R. solani*. Considerable confusion later occurred with regard to these two species, and this led Duggar (28) to redescribe them and collate the synonymy of each.

Until 1903 basidiospores were not definitely associated with either species of Rhizoctonia, although many divergent views were held as to the perfect stage of *R. crocorum*. These are discussed fully by Duggar (28). Recently, however, Buddin and Wakefield (12) have reported *Helicobasidium pur-*

[3] Owing to the complete historical accounts of this group of fungi, already published by previous investigators (28, 59, 62, 74, 79), only those papers are considered which bear relation to the present study.

pureum (Tul.) Pat. intimately associated with *R. crocorum* and, from their study, they consider the balance of the evidence is in favor of the view that *Helicobasidium purpureum* is the perfect stage of *R. crocorum*.[4] Rolfs (72) in 1903 reported a species of Corticium as being definitely associated with *R. solani* and in 1904 (71) proved the relationship by obtaining the sterile Rhizoctonia stage from single spores of the basidiomycete stage. Burt (18) referred the perfect stage, discovered by Rolfs, to *Corticium vagum*. In 1891 Prillieux and Delacroix (64) discovered what they considered to be a fertile species of Hypochnus on a potato stem and named the fungus *Hypochnus solani*. These investigators, however, did not associate their Hypochnus with *Rhizoctonia solani*, already known to occur in Europe. Several European investigators (58, 63, 69) have since shown this identity to exist. American as well as some European investigators prefer to follow Burt's (16) classification of the Thelephoraceae in which the genera Hypochnus and Corticium are differentiated by certain basidiospore characters. Under Hypochnus, Burt places those resupinate species which have rough-wall to echinulate spores that are usually, but not always, colored, while those species with smooth-wall, hyaline, or colorless spores are classified under the genus Corticium. Both *Hypochnus solani* Prill. & Delacr. and *Corticium vagum* have colorless smooth-wall spores. The former, therefore, becomes a synonym of *C. vagum* according to the above classification; this interpretation is followed in the present paper. The Rhizoctonia stage of this species will hereafter be included in the binomial *Corticium vagum*.

Although *C. vagum* grows readily on artificial media, practically all investigators who have studied it have been unable to obtain the perfect stage of the fungus in culture. Thus Atkinson (2, p. 339–342), in discussing damping off of seedlings caused by a sterile fungus ("Rhizoctonia"), states: "Much of the trouble in the nature of damping off both in the forcing house and in the fields is caused by a fungus which has been under study at several different times during the last three years, but up to the present time (1895) has refused all the encouragement, which it has been possible from present experience to offer it, with the hope of inducing it to develop some characteristic fruiting organs, in order that its real nature and affinities might thus be known." Shaw (74) also had the same experience: "It was found impossible to get the perfect stage in cultures on artificial media. It is apparently strictly parasitic." In 1924 Briton–Jones (9) reported that while working in Egypt on sore shin of cotton caused by *Corticium vagum*, the fertile stage had been produced under

[4] An additional paper by these authors (13) appeared after this paper was ready for the press, bringing still more evidence of the genetic connection claimed in their first paper.

experimental conditions. Details of the experiment are not given in the report, but in a letter to the writer, he relates his observance of the Corticium stage on some peanut plants (*Arachis hypogaea* L.) growing in pots in the laboratory garden. These plants had been inoculated with *C. vagum* and had been placed in a shady spot where they were kept continually moist. Müller (59), during the same year, also reported that he obtained the hymenium of *C. vagum* on potato plants inoculated with single-spore cultures of the fungus. This investigator reported further (58) that he obtained the perfect stage in the laboratory by first growing the fungus in a rich nutrient solution and then, after a period of growth, transferring some of the mycelium to flasks containing filter paper saturated with water. Microscopic examinations were made daily after the second day. On the fifth day basidia and basidiospores were discovered in two of the cultures. The spore measurements corresponded to those of Saccardo (73, p. 130). Müller, unfortunately, was unable to duplicate the results obtained in the above experiment. However, his results are thought to represent the nearest approach to obtaining the perfect stage of a Rhizoctonia in artifical culture in the laboratory.

EXPERIMENTAL

Source of Material: Early in October, 1924, while making a study of the violet root rot of alfalfa, a number of diseased plants seriously affected with *Rhizoctonia crocorum* were obtained from an alfalfa field in Cass County, Michigan. These plants were replanted in eight inch pots in the greenhouse at the University of Michigan. The pots were filled with soil from the diseased area of the Cass County field and were watered regularly. They continued to grow in spite of the fact that the tap roots were enveloped in a heavy mycelial felt, characteristic of *R. crocorum* on this host.

On October 21, 1924, there was observed on one of the lower branches of one of the potted plants a white-appearing mass of fungous growth, about 5 mm. in diameter, which resembled the perfect stage of *Corticium vagum*. Anticipating the discovery of the perfect stage of *R. crocorum*, the branch was removed and the material examined under the microscope. Hymenial cells, basidia, and spores were observed.

Owing to the paucity of material, further study was sacrificed in order to pour plates to obtain the fungus in pure culture. Five isolations were made from two series of plates. The growth which followed was similar in all isolations but was white rather than reddish brown or violet as would be expected in *R. crocorum*. Apparently the alfalfa plant from which the isolations were made was affected with two species of Rhizoctonia which the writer believes to be genetically distinct. At no time since its isolation has the new form of Rhizoctonia produced growth that could be mistaken for

that of *R. crocorum*; several pure cultures of the latter were made at about the same time from some diseased alfalfa plants obtained from the same field.

The five isolations made from the mass of hymenial material grew vigorously on Leonian's (49) agar and, after several weeks, it was observed that four of the cultures produced basidiospores while, curiously, one of them, under like conditions, seemingly remained sterile. One of the spore-forming cultures was selected for further study and, for convenience, was designated R-40. The sterile form was numbered R-43.

Following the isolation of this spore-forming Rhizoctonia, a careful examination was made of cultures received from plant pathologists in various parts of the United States. Other cultures isolated from various hosts in Michigan were examined also to ascertain whether they resembled the new Rhizoctonia. Three were found. Two had been isolated from alfalfa and one from bean. One of the alfalfa isolations (R-22) was made by the writer from a damped-off alfalfa seedling grown in a flat of diseased soil obtained from the Cass County field referred to above. The other culture (R-38) was isolated from the roots of an alfalfa plant in Minnesota and was sent to the writer through the courtesy of E. C. Stakman. The third culture (R-44), which somewhat resembled the spore-forming Rhizoctonia, was isolated by the author from a bean which had failed to germinate when planted in wet sphagnum. When grown under similar conditions on Leonian's agar, it was found that of these three only the Minnesota fungus formed spores. The mycelium, hymenial cells, basidia, sterigmata, and basidiospores produced by this fungus were identical with those of the original spore-forming Rhizoctonia isolated by the writer.

Description of the Spore-forming Rhizoctonia. Microscopic examination established the fact that, although the mycelium and sclerotia of this Rhizoctonia are somewhat similar to those of *C. vagum*, the basidia are markedly different. Macroscopic examination also revealed other differences, especially as to color and the abundance of sclerotia. The mycelium of the fungi isolated from alfalfa was white as contrasted with the brown mycelium of *R. solani*; and the sclerotia were neither so large nor so many as those usually formed by the latter fungus. These differences were especially evident when the two fungi were grown on potato-dextrose agar. (Fig. 1.)

The new spore-forming Rhizoctonia belongs to the Basidiomycetes, as is shown by the fact that it forms true basidia, each of which forms 1 to 4 sterigmata. Each of these, in turn, bears a basidiospore.

The outstanding characteristic of the basidia of this fungus is the unusual length of the sterigmata. Actual measurements of these have varied from 13 to 26.5 μ, with an average of 18.8 μ. (Fig. 5, A, and Fig. 6.) The

sterigmata taper gradually from the point of attachment at the basidium to the point of attachment at the basidiospore, the greatest diameter being approximately 2.6 μ. The spores are hyaline, ovate, apiculate, and smooth-wall, having an average size of 7.7×5.2 μ. The average dimensions of the hyaline basidia are 15.6×6.5 μ. No cystidia have been observed. The basidia are arranged in a primitive hymenium, *i.e.*, many small areas, interrupted by sterile areas, are scattered over the surface of the culture in more or less abundance. No continuous fructification of a size easily visible to the eye was ever observed.

From the fact that the hymenium is resupinate, the basidiospores glabrous and hyaline, and no cystidia are present, it would seem that the fungus belongs to the genus Corticium. As *Corticium vagum* was shown by Rolfs (72) to be the perfect stage of *Rhizoctonia solani,* it might be considered

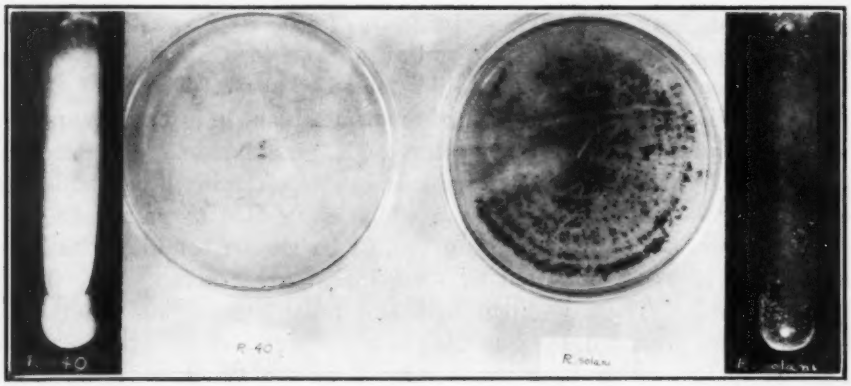


FIG. 1. *Corticium praticola* sp. nov. left, and *C. vagum* B. & C. right, on potato-dextrose agar showing differences in vegetative growth.

that, owing to the somewhat similar vegetative growth of this new spore-forming alfalfa species, its perfect stage can be referred to a position close to the former. However, there appear to be marked morphological differences between the descriptions of *C. vagum* and that given above. The spore dimensions of the alfalfa fungus are much smaller than those of *C. vagum,* for which Burt (18) gives $8–14 \times 4–6$ μ. This mycologist describes *C. vagum* as having 4 to 6 sterigmata, varying in length from 6 μ to 10 μ, while the sterigmata produced by the alfalfa species vary in number from 1 to 4, and vary in length, both in culture and on artificially inoculated alfalfa plants, from 13 to 26 or more microns. (Fig. 5, A, and Fig. 6.) In all illustrations of *C. vagum* examined by the writer (18, 25, 32, p. 115; 54, 59, 64, 74), the basidiospores are shown to be attached to the basidia by sterigmata which are very short, and they are seldom pictured as greater than the length of

the spore (74) and often shown as less than half of the spore length (18). (Fig. 5, C, D, E.) Numerous instances have been observed in the case of the new alfalfa Rhizoctonia in which the sterigmata measured more than three times the length of the greatest diameter of the basidiospore.

Until it can be shown that the perfect stage of *C. vagum*, when produced on artificial media, is similar to that described for the new alfalfa pathogene, there seems to be sufficient morphological evidence to warrant classification of this fungus as a new species of Corticium. The name **Corticium praticola**, sp. nov., is therefore proposed.

CORTICIUM PRATICOLA KOTILA, SP. NOV.

Vegetative hyphae hyaline, Rhizoctonia-like, 6 to 8 μ in diameter, septate with septa at 80 to 100 μ intervals. Sclerotia on artificial media brown, and, in general, smaller and less abundant than those formed by *Corticium vagum*. Sclerotial cells variable in size and shape. Hymenium loose, in minute placques formed by a more or less dichotomous branching of the vegetative hyphae. Terminal cells develop into basidia bearing 1 to 4 sterigmata, the usual number being 3. Basidia average 15.6 μ long and 6.5 μ wide. Sterigmata vary from 13 to 26.5 or more μ long, average 18.8 μ, and taper gradually upward from point of attachment to basidium, greatest diameter 2.6 μ. Basidiospores hyaline, ovate, apiculate, smooth-wall, from 5.2 to 7.8 μ long and from 4.9 to 5.5 μ wide, with average dimensions of 7.7 by 5.2 μ. Cystidia lacking.

Type cultivated in the laboratory; obtained in Michigan. Saprophytic in soil and parasitic on *Medicago sativa* L. in cultivated fields, collected by J. E. Kotila, October, 1924.

Reinoculation of Host. It was not difficult to infect alfalfa with pure cultures of the new Corticium and to recover the fungus from the infected plants.

In several experiments, conducted in the greenhouse during the winter 1924–25, one- or two-year-old alfalfa plants growing in pots were inoculated with pure cultures of the fungus, R–40. After a period of 30 days it was found that infection had taken place. No indication of the perfect stage was observed on these plants. Later (1926), having learned that humidity is a controlling factor for basidiospore formation, the inoculation experiments were repeated.

In one of these repetitions alfalfa seedlings 2–4 mm. in diameter were disinfected in mercuric chloride, 1 : 1000, for two minutes, and then planted in small pots of soil. The pots and soil had previously been steam-sterilized three hours in an Arnold steamer. The soil of 9 pots was inoculated with R–40, while that of a like number was inoculated with the apparently sterile

R-43. After inoculation the pots were placed in a Wardian case in the greenhouse. The floor of this case was covered with wet excelsior in order to make the humidity greater than that of the air in the general greenhouse. After a period of two weeks the data shown in table 1 were obtained.

TABLE 1.—*Reinoculation of alfalfa with Corticium praticola*

Isolation No.	No. of pots	No. of plants	No. plants infected	No. showing perfect stage
R-40 (Fertile)	9	9	9	3
R-43 (Sterile)	9	9	9	0

The basidia, sterigmata, and basidiospores formed upon the three plants which showed the perfect stage, were found to be identical with similar structures formed on artificial media. Both the numbers were reisolated from the infected plants without any apparent change in the character of the fungus. The fertile one formed its basidiospores typically and abundantly, while the other remained apparently sterile.

This experiment was repeated, but, instead of using the Wardian case, the pots were placed in a small, galvanized-iron, glass-cover box near a window in the laboratory. The floor of the box was covered with wet excelsior. Owing to the box being only of slightly larger capacity than was needed for the pots, a higher humidity was obtained than was possible in the Wardian case of the preceding experiment. The results obtained from this trial, shown in table 2, were recorded three weeks after inoculation.

TABLE 2.—*Reinoculation of alfalfa with the C. praticola under conditions of high humidity*

Isolation No.	No. of pots	No. of plants	No. plants infected	No. showing perfect stage
R-40 (Fertile)	5	10	10	10
R-43 (Sterile)	5	10	10	0

As was the case in the preceding experiment, the hymenial cells, basidia, sterigmata, and basidiospores were similar to those obtained on artificial media.

Growth and Reproduction under Controlled Conditions. The establishment of fundamental principles underlying the control of growth and reproduction in plants was due largely to the pioneer work of Klebs (40). This investigator showed the relative importance of external conditions, such as food, moisture, heat, light, oxygen, etc., and their influence on growth and the reproductive processes of plants; he determined how certain of these

factors acted, and was able at will to cause the organisms which he had under observation to remain in the vegetative condition or to proceed to the reproductive phase. Klebs (41) believed that the external factors determined whether growth or reproduction was to take place, the internal factors, in turn, responding to the stimuli exerted by the external environment.

In the experiments reported in the following pages the object has not been to confirm the work of the above investigator. On the contrary, the end in view has been to apply the principles of Klebs to the organism under consideration in order to determine optimum conditions for formation of basidiospores in this species of Corticium.

It is a well-known principle that reproduction in fungi is preceded ordinarily by vigorous vegetative growth. It was, therefore, necessary to learn what were the optimum conditions for vigorous mycelial development before proceeding to determine the optimum conditions for reproduction. These experiments follow.

Food. Early in the work a study was made of the effect of various sugars, including maltose, levulose, glucose, and sucrose, upon the mycelial growth of the spore-forming Corticium. It was learned from this study that the mycelium developed about equally well on any of these sugars. Because maltose appeared to favor the growth in some other cultures of Rhizoctonia, which were being studied at the same time, this sugar was selected as the source of carbon in most of the media employed in the present work.

Inorganic Salts. The favorable effect of potassium dihydrogen phosphate, calcium nitrate, and magnesium sulphate on the growth of fungi having been shown by many investigators, these chemicals were tested out in various amounts to determine the most favorable concentration for the vegetative growth of the Corticium being studied. Coons (22), Leonian (49), and Bonar (8) found certain concentrations of these chemicals to be most favorable for the growth of the fungi which they had under observation. Using as a starting point the concentration found to be favorable by the above investigators in their study of other fungi, a stock solution was prepared according to the following formula:

Potassium dihydrogen phosphate	M/5	4.60 cc.
Calcium nitrate	"	1.28 cc.
Magnesium sulphate	"	1.27 cc.
Maltose	"	8.60 cc.
Agar		2.00 gm.
Water (distilled) to make		100.00 cc.

The concentration of the chemicals used in this formula is considered 1x. In the following experiment the concentration of the chemicals was varied one

at a time, the others remaining at 1x. Concentrations of 1x, 2x, and 4x of each chemical were tried out in 10 cc. quantities in test tubes and the trials were conducted in duplicate. The cultures were grown at room temperature for sixty days. The effect of the concentrations of the above chemicals upon the development of the mycelium of the new Corticium is shown in table 3.

TABLE 3.—*Effect of concentration of various chemicals upon the growth of Rhizoctonia (R-40)* (*Scler.* = *sclerotia*)

Chemical	Days at 25° C.	Concentration					
		1x		2x		4x	
		Mycel.	Scler.	Mycel.	Scler.	Mycel.	Scler.
Potassium dihydrogen phosphate	7	I[4]		III	II	III	
	10	II		II	I	III	I
	14	II–		II–	I	II	I
	60	II		II	I	III	I
Calcium nitrate	7	I		III	II	III	II
	10	II		III	II	III	II
	14	II–		II	I	II	I
	60	II		III	I	III	I
Magnesium sulphate	7	I		II		III	
	10	II		II		II	
	14	II–		II	I	II	I
	60	II		III	I	III	I

[4] Growth: I–poor; II–fair; III–good.

In a week after the test tubes were inoculated the cultures had extended over the entire surface of the media, thus obscuring the accuracy of the readings after that period. Observations made 10 days after the experiment had been started indicated that the higher concentrations produced only slightly better growth than the 1x in the case of potassium dihydrogen phosphate and magnesium sulphate. In the case of the calcium nitrate, however, the increased growth in the 2x and 4x concentrations was especially pronounced.

Organic Nitrogen. Of the various carriers of nitrogen only the more common forms, malt extract, peptone, and asparagin were compared. Of the three, malt extract was found to cause by far the most abundant mycelial development.

Using the results obtained in the preceding experiments, the concentrations of the various substances most favorable for growth were selected and a medium was prepared according to the following formula:

Potassium dihydrogen phosphate	1.25 gm.
Calcium nitrate	2.36 gm.
Magnesium sulphate	0.59 gm.
Maltose	6.25 gm.
Malt extract	6.25 gm.
Agar	20.00 gm.
Distilled water to make	1000.00 c.c.

Autoclave at 10 pounds for 15 minutes.

The Corticium under consideration grew well on this medium and formed spores very abundantly. With few exceptions, this medium was used in all of the experiments in relation to environmental factors. Coons' (22) synthetic medium, because of its greater transparency, was found superior when it was necessary to make microscopic observations through inverted petri dishes. This medium also was used in that part of the present investigation dealing with the isolation of single spores from basidia while under constant observation through the microscope.

Having obtained a medium highly favorable for vegetative growth, the following experiments were conducted to determine optimum conditions for the formation of basidiospores.

Moisture. The effect of humidity on spore formation of R-40 was determined by a series of experiments in which cultures were grown in test tubes of malt-extract agar, prepared according to the foregoing formula. The cultures were grown at room temperature in incubators provided with glass doors. A range of humidity was obtained by placing pans of water in the incubators. The check cultures were grown on a laboratory table adjacent to the incubators. Humidity readings were made by means of Lambrecht polymeters. A typical range of humidity and the effect upon basidiospore formation obtained in these experiments are shown in table 4.

TABLE 4.—*Effect of humidity upon spore formation in Rhizoctonia R-40 (C. praticola)*

Place	Humidity percentage	Basidiospore formation
Incubator No. 1	90.0	Meager
" " 2	82.0	Fair
" " 3	65.0	Abundant
Laboratory table	32.0	None

It is obvious that the moisture content of the air is a very important factor in basidiospore formation in *C. praticola.* The above results confirm field observations which have shown that the Corticium stage of *R. solani* on potato stems is more prevalent during seasons of abundant rainfall and consequent high atmospheric humidity than in comparatively dry

seasons. The correlation of abundant moisture with the perfect stage of this fungus has been recognized by many investigators (9, 62, 74).

Temperature. Richards (66, 67, 68) showed that the *C. vagum* studied by him grew within a temperature rage of 4.6° to 32.6° C., the optimum being between 25° and 27° C. He also found that the soil temperature influenced the pathogenicity of the fungus and that the optimum temperature for tissue destruction on potato, pea, bean, and cotton was approximately 18° C. Müller (59) reported a temperature range of 4.5° to 30.8° C. for the *Hypochnus solani* (*R. solani*) he had under observation. The latter investigator found 24° C. to be the optimum temperature for growth of his organism.

The effect of temperature on vegetative growth and basidiospore formation of the species of Corticium studied by the writer was determined in two experiments. Duplicate cultures in test tubes were grown at various temperatures obtained in the compartments of a differential thermostat, one end of which was cooled in a tank containing ice and brine, while the other end was heated by means of an electric-light bulb. In the first experiment a range of temperature from 9.6° to 34.1° C. was obtained in the seven compartments of the thermostat. The cultures were grown for two weeks when the following observations were made:

Very feeble growth had occurred at the minimum and maximum temperatures.

Optimum growth occurred at 19° to 21° C.

No provision was made to maintain humidity in the compartments of the thermostat in this experiment, hence no basidiospores were formed.

TABLE 5.—*Effect of temperature upon growth and basidiospore formation of Rhizoctonia (R-40). (C. praticola)*

Temperature[5] (Centigrade)	Mycelium	Sclerotia	Basidiospores
2.1	0	0	0
9.9	I[6]	0	0
16.0	III	IV	I
18.6	IV	III	II
20.7	IV	II	III
24.3	V	I	I
35.2	II	0	0

[5] Average daily temperature for 30 days.

[6] No growth, sclerotia, or spores. 0
Growth poor, sclerotia and spores few I
Growth excellent, scler. and spores many V

In repeating the experiment a higher humidity was obtained by placing absorbent cotton, saturated with water, in each compartment and by the addition of water from time to time as required. The temperatures were recorded daily and, after 30 days, the cultures were removed and the data, shown in table 5, were obtained.

As shown in table 5, the optimum temperature for mycelial growth is 24.3° C. which is very close to that reported by Müller working with *R. solani*. However, the differences in growth between 18.6° and 24.3° C. were not very marked. The temperature range for sclerotium and basidiospore formation was found to be the same (16.0° to 24.3° C.). The optima, however, were different. Sclerotia were most numerous at 16° C., while basidiospores were most abundant at 20.7° C.

Light. In nature the perfect stage of *C. vagum* is found at the base of the stems of the plants on which it occurs and sometimes it extends 6 to 20 cm. up the stem or out along the first branches. While the light is somewhat subdued in most situations where *C. vagum* is found, occasionally the fruiting stage is observed under fully exposed conditions. In order to determine whether light is essential to the formation of the perfect stage of *C. praticola,* the following experiment was performed. Twenty test tubes containing malt-extract agar were inoculated with transfers from a vigorously-growing culture of Rhizoctonia (R-40). Ten cultures were placed in a test-tube rack in a light-proof box. The ten remaining cultures were placed in a similar test-tube rack exposed to light. Both sets of cultures were placed in an incubator having a humidity of approximately 90 per cent and a temperature of 24° C. The incubator was placed about eight feet from an east window. A 500-Watt-electric light was placed near the glass door of the incubator so that daylight could be supplemented by electric light on cloudy days. As in previous experiments, the cultures were allowed to grow for 30 days before the data shown in table 6 were obtained.

It was observed during the course of the experiment that those cultures nearest the source of light were the first to form spores and, at the conclusion of the test, basidiospores were more abundant in the five cultures nearer the source of light than in the five farther removed (Cultures Nos. 16 to 20). It is interesting to note that sclerotium formation occurred only in the cultures kept in the dark.

Some basidiospores were formed under conditions of darkness, but it would appear that light strongly stimulates spore formation.

Reaction of the medium. Although many fungi are known to tolerate a wide range of hydrogen-ion concentration in the substrata upon which they grow, some are known to be more or less restricted. *Actinomyces scabies* (Thax.) Güssow has long been associated with alkaline soils, and it is common knowledge amongst potato growers that common scab does not

TABLE 6.—*Effect of light upon basidiospore production of Rhizoctonia (R-40). (C. praticola)*

Culture No.	Conditions	Basidiospores	Sclerotia
1	Light	III[7]	0
2	"	III	0
3	"	III	0
4	"	III	0
5	"	III	0
6	Dark	I	I
7	"	I	I
8	"	I	I
9	"	I	I
10	"	I	I
11	"	I	I
12	"	I	I
13	"	I	I
14	"	I	I
15	"	I	I
16	Light	II	0
17	"	II	0
18	"	II	0
19	"	II	0
20	"	II	0

[7] Basidiospores abundant III
" meager I

occur on potatoes on acid soils. Gillespie (33) showed that the growth of this potato-scab organism was inhibited at a reaction of pH 5.2 or less. Whereas, common scab of potatoes is limited to nonacid soils, the disease caused by Rhizoctonia is known to occur on potato plants grown on a great variety of soil types irrespective of hydrogen-ion concentration of such soils. Likewise, the *C. vagum* stage has been observed under a wide range of these conditions. The tolerance shown by *R. solani* in nature was found to hold in the case of Rhizoctonia R-40 when grown on artificial media.

Coons' synthetic medium, in test tubes, was adjusted colorimetrically to various hydrogen-ion concentrations, ranging from pH 4.0 to pH 7.6, by the addition of N/10 hydrochloric acid or N/10 sodium hydroxide. The unadjusted medium had a reaction of pH 5.2. Three tubes adjusted to each reaction were inoculated and the cultures grown for 14 days at 24° C. in an incubator having a humidity of approximately 60 per cent.

The reaction of the medium within the range tested (Table 7) had no effect either on the growth of mycelium or on the formation of basidiospores in the case of the fungus under consideration. The results obtained

were so uniform that the effect of the reaction of the substratum on the fungus was no further studied.

TABLE 7.—*Effect of reaction of substratum upon basidiospore formation of Rhizoctonia R-40.* (*C. praticola*)

Reaction	Basidiospore formation	
	8 days	14 days
pH 4.0	II[s]	III
4.6	II	III
5.2	II	III
6.2	II	III
7.6	II	III

[s] Basidiospores few I
" numerous III

Oxygen. In an earlier study of *R. solani*, it was learned that an abundant supply of air was required and that the fungus did not remain alive for more than 4 days in cultures kept sealed in test tubes of 30 cc. capacity. In the present study of Rhizoctonia R-40, it was noticed that basidiospores in test-tube cultures were first formed on that part of the medium near the tip of the slant. In petri-dish cultures, the hymenial cells formed first and their basidiospores occurred on the outer edge of the inner surface of the top plate nearest the source of air.

Klebs (41) was of the opinion that oxygen exerted little or no influence on the appearance of reproductive stages of *Sporodinia grandis* Link. and showed that transpiration was the controlling factor. In order to determine more definitely what influence oxygen had upon the growth and basidiospore formation of *C. praticola*, several experiments were carried out as follows:

Cultures were made on Coons' synthetic agar in petri dishes. The cultures were placed on pieces of window glass and covered with large bell jars fitted with two-hole rubber stoppers. Short pieces of glass tubing were inserted into the stoppers and to one was atached a piece of rubber tubing which extended to the bottom of the bell jar. Air under pressure was forced through one bell jar continuously. The air of the second bell jar was allowed to diffuse in and out unassisted. Abundant humidity was supplied in both bell jars by means of absorbent cotton saturated with water. After two weeks' growth it was observed that basidiospores had formed very abundantly in the aerated cultures and very feebly in the nonaerated set.

A second experiment was performed in which petri dishes, inoculated as before, were placed in two Novy jars. Air under pressure was passed through one of the jars for 15 minutes daily after which the jar was sealed. Oxygen[9] was passed through the other jar each day for a similar length of time after which the jar was likewise sealed. After two weeks the Novy jars were opened and the cultures examined. The aerated cultures again had formed hymenial cells and basidiospores abundantly, while the oxygenated cultures were like those of the nonaerated set of the preceding experiment and indicated that an atmosphere containing a high percentage of oxygen is not favorable for basidiospore formation in the fungus concerned.

The results obtained in the above experiments seem to indicate that a study of the respiration quotients of this fungus would yield interesting results. However, such an extensive undertaking, as reported by Novy, Roehm, and Soule (61) was not attempted in the present study.

INHERITED FACTORS

From the preceding experiments it follows that several different external conditions take an important part in the control of basidiospore formation. Abundant humidity, a proper temperature, an optimal oxygen supply, and a determined food quality are necessary for their best development. Under these optimum conditions the spore-forming units developed and produced many spores. However, when other isolated units of similar origin were grown under the same conditions, they remained in the vegetative stage, indicating that, in addition to external conditions, certain inherited potentialities are placed differently in the different spores produced by this otherwise fertile fungus (R-40).

Heterothallism. The occurrence of heterothallism in fungi was reported first in the Phycomycetes by Blakeslee (6, p. 319). Considerably later the phenomenon was found present in the Basidiomycetes by Bensaude (5), Kniep (45), Buller (14), Mounce (57), Hanna (35), Newton (60), and others. Heterothallism has also been demonstrated in the Ascomycetes by Dodge (27) and by Shear and Dodge (75); in the Ustilaginales by Kniep (46) and by Stakman and Christensen (77); and by Craigie (23) in the Uredinales.

Müller (59), basing his opinion on the behavior of single-spore cultures inoculated on potato plants growing in pots in the greenhouse, concluded that "*Hypochnus solani*" (*C. vagum*) is homothallic.

In describing the isolation of *Corticium praticola* mention was made of the fact that four of the five isolations made by the writer formed

[9] The oxygen used was a product of the Air Reduction Sales Co., Detroit, Michigan, whose analysis showed the gas to be 99.5 per cent oxygen.

basidiospores in culture, while, curiously, one remained apparently sterile. It was related further that search through the stock cultures of the Rhizoctonias on hand revealed two more apparently similar ones which likewise remained sterile. These three sterile cultures have been designated as R-43, R-22, and R-44, respectively, while the fertile strain heretofore referred to as R-40 was selected for comparative study. In attempting an explanation of the behavior of the first five isolations made from the original mass of hymenial cells and basidiospores obtained from the alfalfa stem, the following hypothesis presented itself: That the four spore-forming isolations had come from bits of hymenial material which had one kind of sex value, while the seemingly sterile offshoot was possibly a single-spore isolation of a different sex value. Such an hypothesis would assume that the fungus is heterothallic.

In order to test the validity of the hypothesis a preliminary experiment was performed in which the apparently sterile form R-43 was grown in the presence of R-22 and R-44. The latter cultures also were grown together. The matched cultures were grown at room temperature in small capsules of approximately 25 cc. capacity, each of which contained 10 cc. of malt-extract agar. The cultures were kept on a laboratory table about five feet distant from a north window. A month later microscopic examination showed that basidia, sterigmata, and spores, similar to those formed by R-40, were present in the capsules containing the cultures arranged thus: R-43 x R-22 and R-43 x R-44 but none were found in the capsule in which the cultures were matched as follows: R-22 x R-44.

The interesting results obtained in the preliminary experiment led to a more comprehensive confirmatory test. The three apparently sterile forms were again matched in all possible combinations. The cultures were grown in capsules as before and observations were made after 30 and 45 days. The data obtained from this experiment (see Table 8) were not so conclusive as one might expect from the results of the preliminary experiment. Basidiospores were formed only in one culture containing the matched forms and, as was the case in the first trial, the basidiospores occurred in only a small area. The mycelia of the two fungi intermingled and there was no microscopic evidence to indicate conjugation such as has been described by Blakeslee (6, p. 319).

The experiment was repeated numerous times but in only one additional case were basidiospores formed, when R-43 was grown in the presence of another one of these forms. Here again spore formation was not abundant. In all of the experiments the check R-40 formed a hymenium and basidiospores abundantly over the entire surface of the mycelial base as well as on the mycelium which had grown up to the sides of the containers.

TABLE 8.—*The results obtained by matching possible sexual strains of Corticium praticola*

Mating	No. of cultures	Results			
		30 days		45 days	
		Pos.	Neg.	Pos.	Neg.
22 x 22	10	0	10	0	10
22 x 43	10	0	10	0	10
43 x 43	10	0	10	0	10
43 x 44	10	1[10]	9	1[11]	9
44 x 22	10	0	10	0	10
44 x 44	10	0	10	0	10
40 x 40 (CK)	1	1	0	1	0

[10] Hymenial cells only.

[11] Basidiospores.

Such evidence as was obtained from the above experiments was, of course, inconclusive. Thinking that stronger proof of heterothallism might be obtained by mating single-spore cultures of the spore-forming Rhizoctonia R-40, twenty such cultures were made. These single-spore isolations were made by the Kauffman (39) method of distributing a dilute spore suspension by means of a fine pipette over the surface of a previously poured and hardened plate of malt-extract agar. Single spore were then cut out. Of the twenty single-spore isolations obtained, two formed basidiospores similar to and as abundantly as the parent culture. The eighteen which were apparently sterile could be classified into two groups according to rate of growth. Representatives of these two groups are shown in figure 2 and in figure 5, F. The differences in type of growth were very evident during the first few days after transfers were made. However, after the mycelia of the slow-growing cultures had covered the surface of the medium, macroscopic differences were no longer striking. It is interesting to note that Müller (59) observed differences both in the rate of growth and in the virulence of the single-spore cultures of *Corticium vagum* (*Rhizoctonia solani*) which he had under observation.

The sterile single-spore forms of Rhizoctonia R-40 were grown together in various combinations under conditions known to favor spore formation in the parent culture. No spores were observed in any of the matched cultures. Finally, all of the apparently sterile single-spore forms were matched in all possible ways, as shown in table 9. The experiment was performed in duplicate and four capsules were inoculated from the parent R-40 culture as a check on the favorableness of the external environment for basidiospore formation.

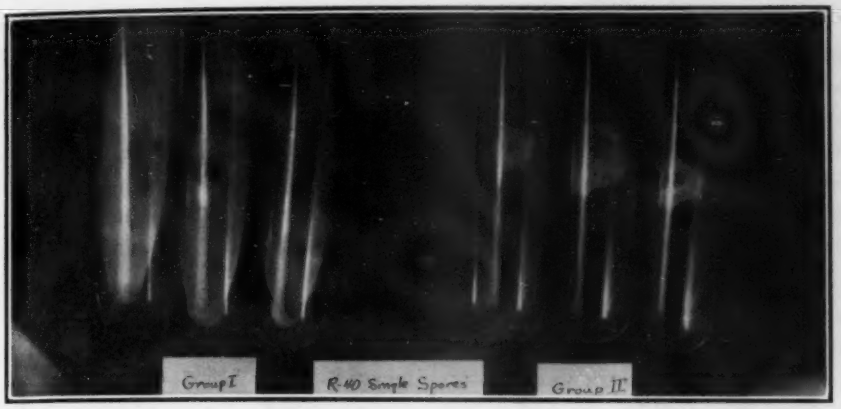


FIG. 2. Groups of rapid- and slow-growing single-spore cultures of *C. praticola*.

TABLE 9.—*Effect of matching single-spore cultures of Rhizoctonia R-40*

		Group I										Group II							
		Rapid growers										Slow growers							
		1	2	3	4	5	6	7	14	18	20	8	9	10	11	12	13	16	19
Group I	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Group II	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

The cultures were grown 30 days and then examined with hand lens for evidence of basidiospores. All suspicious cultures were reexamined under the microscope. In no case were basidiospores observed except in the check cultures and in these spore formation could easily be detected by the experienced, even if unaided, eye.

Hanna (35) has shown that in the four-spore *Coprinus lagopus* Fr. sex is determined by certain factors which segregate according to Mendelian principles, and that single-spore mycelia from any individual fruit body of this fungus belong to four sexual groups. Complete fertility results when union occurs between any two mycelia lacking a common factor. In the light of Hanna's results, it might be assumed that the failure to obtain the perfect stage in the matching experiments described above was due to the fact that all of the single-spore forms possessed some common factor. In order to determine whether this was actually the case, it was necessary to isolate single basidiospores from individual basidia and to determine the behavior of these single-spore cultures when grown alone and with each other in various combinations.

The dry-needle method of making monosporous cultures of Hymenomycetes and other fungi described by Hanna (36) is not applicable to fungi which produce a loose hymenium as is the case in *Corticium praticola*. The small size of the spores, their hyaline color, and the lack of uniformity in the number of spores formed by the basidia all indicate the unreliableness of any method of spore isolation from single basidia in which the basidia and spores are not under constant observation during the process of isolation.

Isolation of single spores of Corticium praticola (R-40) from individual basidia. The basidiospores of the form R-40 are formed on long sterigmata which extend out from the basidium in such manner that the individual spores are usually, relatively considered, at a considerable distance apart from each other. This fortunate position of the spores suggested the possibility of their isolation by using the technique reported by Barber (3) and Chambers (20) for the isolation of single bacterial cells.

After numerous preliminary trials the following technique was adopted. Cultures of the fungus were grown in petri dishes on Coons' synthetic agar under environmental conditions favoring spore formation. The medium was sterilized by autoclaving instead of by steaming on three successive days.[12] After 14 days hymenial cells, basidia, and spores were usually found to be abundant and were formed near the surface of the medium. A petri-dish culture containing basidiospores was placed, with the top plate removed, on the stage of a microscope to which was attached a "Barber micropipette manipulator," equipped with two glass needles. The diameter

[12] Coons, in conversation with the writer, expressed his belief that sterilization of his medium by autoclaving instead of by steaming on three successive days causes some change in the medium which is not favorable for mycelial growth. The suppression of mycelial development is, in this method of spore isolation, an advantage in that much of the difficulty incident to tangling of mycelia on the needles and loss of spores already picked is eliminated.

at the points of these needles was approximately ten microns.[13] Rapid drying-out and collapsing of the hymenial cells and basidia in the petri dishes was prevented by placing the microscope in a moist chamber. The humidity of the atmosphere of the small culture room, in which the isolations were made, was further increased by keeping the floor wet. Illumination was provided by a small electric microscope lamp placed directly under the condenser of the microscope. Heat from the light was absorbed by water contained in a flat bottle placed directly over the lamp. The low-power 16 mm. objective and No. 10 ocular were used in the isolation of single basidiospores. This was accomplished by first lowering the points of the needles, previously centered under the microscope, to a point approximately 5 mm. above the surface of the medium. The objective of the microscope was then lowered until the points of the needles were in focus after which it was again lowered until the hymenial cells, basidia, sterigmata, and spores could be seen. The petri dish was next moved about until a fungus-free area was found. The needles were were cleaned by lowering the points into the agar of this clear area and by forcing them through the medium in various directions by means of the lateral and longitudinal adjustments of the micropipette manipulator. After cleaning, the needles were raised so that the points were above the hymenial cells and the aerial portions of the fungus. The petri dish was moved about until a basidium was found on which all of the spores could be seen. (Fig. 6.) One of the needles was then lowered and by manipulation of the various adjustments was brought into contact with a basidiospore. On drawing the needle away the mature spore could be seen adhering to the needle. (Fig. 6, D.) By further manipulation a second and sometimes a third spore were picked on the same needle at some distance apart. At times both needles were used, picking one basidiospore on each in the case of a two-spore basidium, or one on one needle and two on the other in the case of a three-spore basidium, or two on each when the spores were picked from a four-spore basidium. After the spores had been removed from a basidium, the objective of the microscope and the needles were raised so that the petri dish containing the culture could be removed and replaced by another containing the same medium. The bottom plate of this dish had been previously marked as illustrated in figure 3. The needles were lowered again to a point about 5 mm. above the surface of the medium and the objective of the microscope was focussed downward until the needles were visible. The presence of the basidiospores was checked. The petri dish was then moved about until the desired marked area was centered under the microscope. The location was confirmed by focussing down through the medium, after which the objective

[13] The technique reported by Barber (3) was utilized in the preparation of the microneedles used in the present investigation.

was raised to a point slightly above the surface of the agar. One of the needles bearing basidiospores was then lowered until it could be seen. The objective and needle were lowered alternately until the surface of the medium was in focus. The needle was then lowered so as to come into contact with the medium. The film of moisture on the surface of the medium released the basidiospore from the needle, raised immediately afterward to

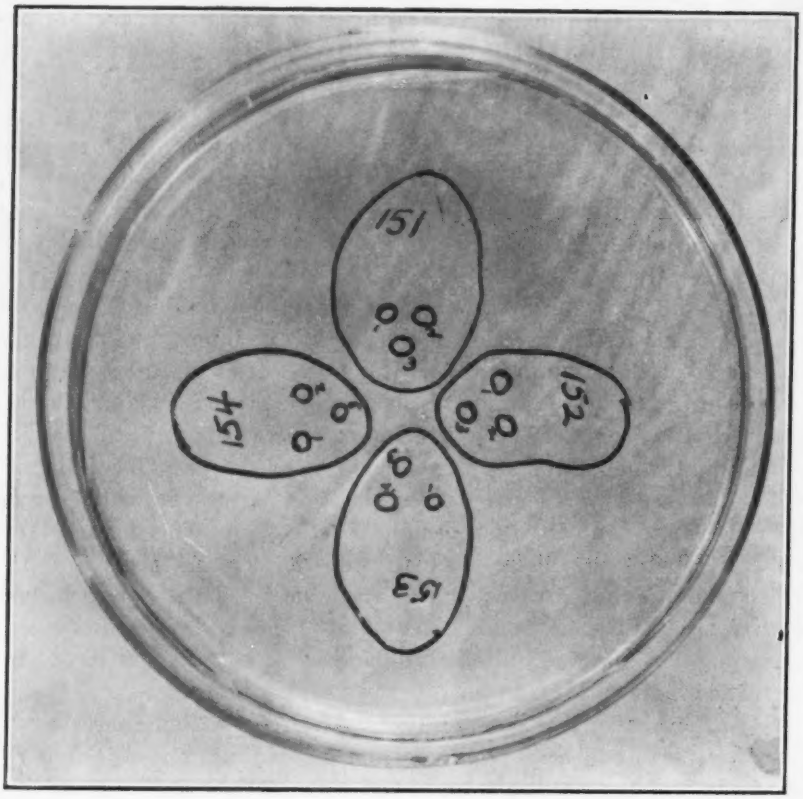


FIG. 3. Isolation of single spores. Method of marking petri dishes.

prevent a second spore from being deposited in the same area. A slight manipulation of the fine adjustment of the microscope revealed the basidiospore lodged on the surface of the medium. The petri dish was then moved so that another marked area was centered upon the microscope and another basidiospore was planted like the first, and the process was repeated for the other spores which had been isolated from the same basidium. After planting the basidiospores, the objective of the microscope and the needles were raised and the petri dish exchanged for the one containing the culture and

the operation of picking basidiospores was repeated. After becoming accustomed to the manipulation of the various adjustments of the pipette manipulator basidiospores could be picked from the one dish and planted in another in a relatively short time.

The petri dishes containing the planted basidiospores were examined microscopically through the bottom of the plates after 24 hours for evidence of germinating spores and after 48 hours all that had germinated were transplanted to test tubes containing slants of Coons' synthetic-agar

TABLE 10.—*Behavior of single-spore cultures isolated from the spore-forming Rhizoctonia R-40. (C. praticola)*

Basidium No.	Number of spores				Behavior	
	Formed	Isolated	Germinated	Grew	Fertile	Sterile
6	3	3	2	2	1	1
7	2	2	2	2	2	0
10	2	1	1	1	1	0
11	4	2	1	1	1	0
17	3	3	1	1	1	0
18	3	1	1	1	1	0
23	2	1	1	1	0	1
24	2	2	1	1	1	0
105	2	2	1	1	1	0
106	3	1	1	1	1	0
107	3	2	1	1	1	0
108	3	1	1	1	1	0
113	3	1	1	1	1	0
114	3	3	3	1	1	0
116	4	2	2	1	1	0
117	4	1	1	1	1	0
118	2	1	1	1	1	0
121	2	2	2	1	1	0
122	3	2	1	1	1	0
123	3	1	1	1	1	0
133	4	4	4	2	2	0
134	3	2	1	1	1	0
135	2	2	1	1	1	0
137	2	2	2	1	1	0
142	3	3	2	1	0	1
144	3	3	1	1	1	0
145	3	3	2	2	2	0
146	4	4	3	2	2	0
147	2	1	1	1	1	0
149	3	3	3	2	2	0
150	3	3	3	2	1	1
Totals..	88	64	49	38	34	4

medium. (Fig. 5, F.) The transfers were made by means of a sterile spatula made from a piece of a safety-razor blade fused into a glass rod.

Behavior of pedigreed single-spore strains. During the present investigation a total of 225 basidiospores were isolated from 150 individual basidia by the method described above. Of this number, 123 germinated and 86 continued to grow.

The behavior of the single-spore cultures isolated from 31 basidia of Rhizoctonia R-40 is shown in table 10, from which it will be seen that nearly all spores isolated from individual basidia were fertile irrespective of origin. The single spores isolated from 2-, 3-, or 4-spore basidia behaved

TABLE 11.—*Behavior of the second single-spore progeny obtained from one of the first single-spore cultures ($B6_2$) of R-40. (C. praticola)*

Basidium No.	Number of spores				Behavior	
	Formed	Isolated	Germinated	Grew	Fertile	Sterile
40	2	1	1	1	1	0
41	3	2	1	1	1	0
43	4	1	1	1	1	0
48	2	2	1	1	1	0
49	4	1	1	1	1	0
51	2	2	2	2	2	0
52	4	2	1	1	1	0
53	2	2	2	2	2	0
54	3	1	1	1	1	0
59	3	2	2	2	2	0
62	3	2	2	2	2	0
66	3	1	1	1	1	0
68	3	1	1	1	1	0
72	3	1	1	1	1	0
73	3	1	1	1	1	0
75	4	1	1	1	1	0
76	3	1	1	1	1	0
78	4	1	1	1	1	0
79	4	2	1	1	1	0
80	2	2	2	2	2	0
81	4	2	2	2	2	0
83	3	2	1	1	1	0
84	3	3	1	1	1	0
86	3	1	1	1	1	0
89	4	2	1	1	1	0
90	3	2	2	1	1	0
91	4	2	2	2	2	0
92	3	1	1	1	1	0
Totals	88	44	36	35	35	0

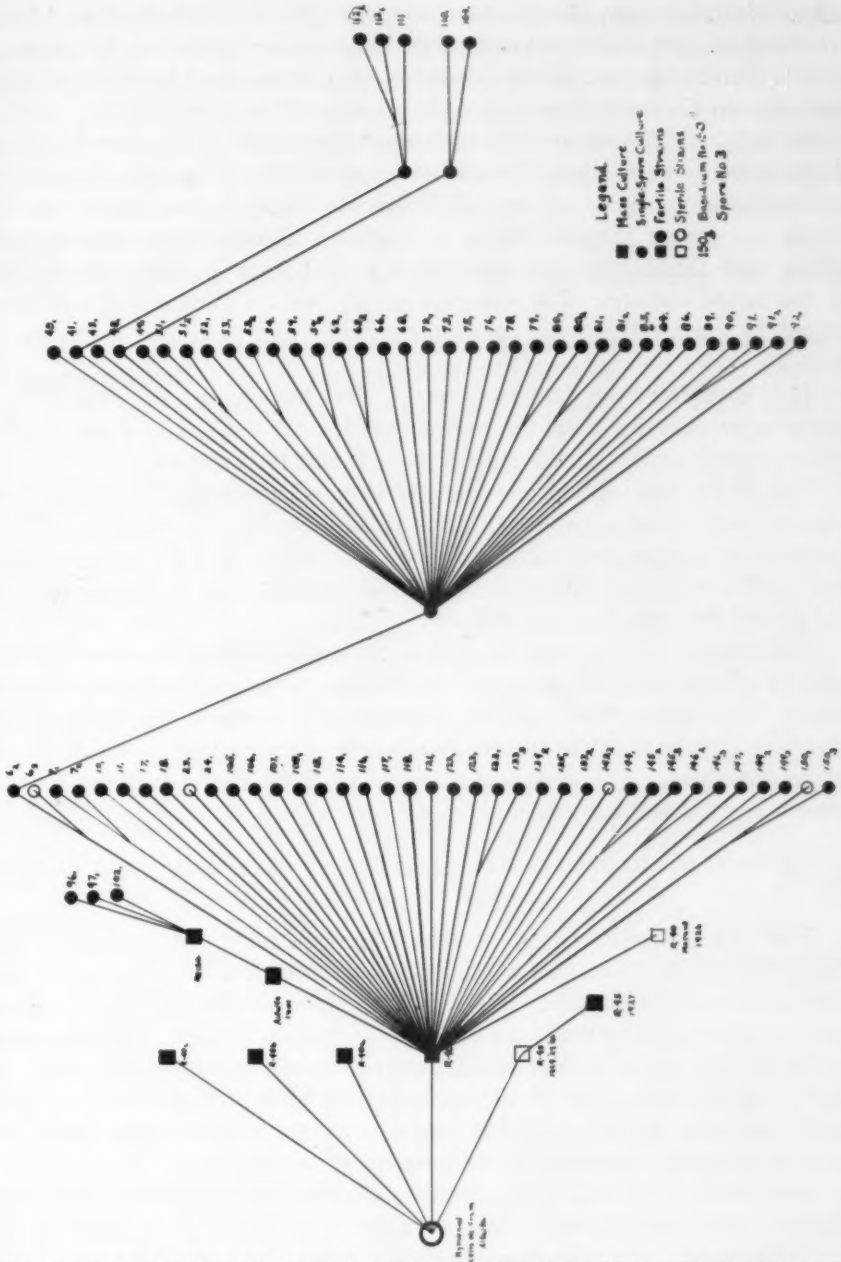


FIG. 4. Graph showing behavior of the spore-forming Rhizoctonia and its single-spore progeny.

alike. *Note, however, that four single-spore cultures were sterile and have remained so.* All attempts to stimulate basidiospore formation, by growing these cultures together in all possible combinations and in various other ways known to favor reproduction, have resulted in failure.

In order to determine whether the progenies of these spore-forming, single-spore cultures would behave in the same way as the parent culture, one fertile single-spore culture $B6_2$ (basidium No. 6, spore No. 2) was selected and grown in petri dishes as described above. When basidia and spores were abundant single spores were picked from 54 individual basidia of the latter culture. The spores from 28 basidia germinated and continued to grow. The behavior of these single-spore cultures is shown in table 11.

It is seen from the data in table 11, that the single-spore culture $B6_2$ has greater stability than the parent culture (R-40). All of the single-spore progeny of this fertile culture were found to be fertile.

The study was carried one step farther and single basidiospores were isolated from two single-spore cultures of the second series, viz, $B6_2$. Three single-spore cultures were obtained from two basidia of $B41_1$ and two from two basidia of $B48_1$. All of these formed basidiospores as abundantly as the parent and grandparent cultures.

The behavior of the spore-forming R-40 and its progeny is shown graphically in figure 4 and indicates that the fungus under consideration is homothallic. The assumption that the presence of a common sex factor is responsible for the negative results obtained in the matching of sterile forms is not sustained. The apparent sterility in these forms must be due to some other unknown cause.

THEORETICAL POSSIBILITIES INVOLVED IN THE PRESENT STUDY OF THE FORM R-40 OF C. PRATICOLA

Viability of basidiospores. It was observed during the progress of the present study that many of the basidiospores isolated by the glass-needle method failed to germinate. *It was further observed that after some spores had germinated the germ tube failed to continue to grow.* Of the total of 225 basidiospores isolated, 54.6 per cent germinated but only 36.4 per cent of the total number picked continued to grow. The failure of some basidiospores to germinate and of others to continue growth after germination opens up the question of the underlying causes.

Conditions involved. The question of technique might be raised, and it is very probable that the low percentage of germination obtained in the early isolations made from form R-40 was due largely to faulty technique. However, after the technique had been mastered sufficiently so that complete sets of basidiospores could be isolated very quickly—the entire opera-

tion of picking and planting the spores from a three-spore basidium requiring not more than five minutes—the percentage of germination had improved only 23.8 per cent. It would seem unlikely, therefore, that faulty technique was entirely responsible for the behavior of the basidiospores and especially of those failing to continue growth after germination. A number of typical cases, in which complete sets of basidiospores were isolated and in which one or more of them failed to continue to grow after germination, are shown in table 12.

TABLE 12.—*Behavior of complete sets of basidiospores isolated from individual basidia of R-40. (C. praticola)*

Basidium No.	Number of basidiospores			
	Formed	Isolated	Germinated	Grew
105	2	2	1	1
114	3	3	3	1
119	2	2	2	0
121	2	2	2	1
127	2	2	2	0
128	3	3	1	1
129	3	3	1	1
131	2	2	2	0
133	4	4	4	2
135	2	2	1	1
137	2	2	2	1
142	3	3	2	1
143	3	3	2	2
144	3	3	1	1
145	3	3	1	1
146	4	4	3	2
148	3	3	1	0
149	3	3	3	2
150	3	3	3	2

In many of the cases shown in the above table basidiospores no. 2 and no. 3 continued to grow and no. 1 failed to do so. Basidiospore no. 1 represents the last spore picked from a given basidium and the first one planted after isolation. This would indicate that if the method were faulty, this basidiospore should have had considerable advantage over the others and should have been the one to germinate and continue to grow. Müller (59) studied the viability of the basidiospores of *Corticium vagum* which he had under observation and found that they did not remain viable beyond 44 days. It is presumed that the spores remained viable for that length of time and, if so, it would seem highly improbable that the basidiospores of the apparently closely related Corticium herein considered had sufficient

time to lose their viability through drying out during the few minutes elapsing between the isolation and planting of the spores.

That variations in the medium used and on which the spores were transplanted are not a factor is shown by the details of procedure. All of the basidiospores from a given basidium were planted in marked areas not more than 1 cm. distant from each other in the same petri dish and all of the basidiospores isolated from three other basidia were planted in similarly marked areas in the same dish, all of the spores being planted within a radius of 2½ cm. of the center of the dish. (Fig. 3.) It would seem that the external conditions were alike for all spores. Yet, under these conditions, some of the basidiospores germinated and grew rapidly while others, when examined under the microscope 24 hours after isolation, were found to have germinated and to have made very feeble growth. In some cases germ tubes were formed which were from 6 to 12 microns long. Daily observations made on some of these germinated basidiospores for a period of one week failed to reveal any further growth.

The improbability that external conditions were responsible for the failure of some basidiospores to grow having been pointed out, the probable effect of other conditions should be considered.

What effect has maturity of basidiospores on germination and growth? Experience derived from continuous isolation of basidiospores of all sizes, and consequently in all stages of maturity, from hundreds of basidia, has shown that a spore at the proper stage of maturity is not difficult to isolate by the needle method herein described. With the slightest touch of the needle the mature basidiospore can be dislodged from its sterigma; whereas, it is impossible to remove an immature spore by this method. In two cases it was observed that basidiospores were actually released from their sterigmata and had attached themselves to the needle before the needle had come in contact with the spores.[14] The immature basidiospore, after contact with the needle, adheres to it so strongly that when the needle is drawn away the sterigma is bent until the force of cohesion overcomes the force of adhesion and the sterigma with its spore flies back to its original position on the basidium. The process can be repeated until the sterigma,

[14] Although violent discharge of spores, as described by Buller (14) for other Basidiomycetes, was not observed except in these two cases, there is no question in the mind of the writer but that this phenomenon takes place in connection with the liberation of the basidiospores of the fungus under investigation. Many times making single-spore isolations it was observed that plates containing great numbers of basidiospores when the cover plate had been removed, had, a short time later, very few that could be removed from their respective sterigmata. A great many sterigmata from which spores had been released could be seen about the plate, and many of the basidiospores were observed on the surface of the agar not far removed from the basidia, or on adjacent aerial hyphae of the fungus. The difficulty experienced during the early part of the work from a too rapid discharge of basidiospores was overcome somewhat by increasing the humidity of the atmosphere surrounding the isolation apparatus.

with its basidiospore still attached, is so badly injured that it collapses and is drawn in amongst the surrounding basidia and hymenial cells. It would seem, therefore, that a basidiospore which can be removed from its sterigma by the slightest contact with the needle and which is planted within two minutes after its isolation is sufficiently mature to germinate and to continue to grow.

Lethal factors have been found associated with many animals and plants. These factors have been reported to occur in yellow mice by Cuènot (24) whose work was confirmed by Little (52). Morgan (56) and his students have reported 25 or more lethal factors in *Drosophila melanogaster* Meig. In the plant kingdom these factors were postulated by de Vries and have been shown to occur in corn by Lindstrom (51), in snapdragon by Bauer (4), and in Oenothera by Shull (76), and other investigators. The lethal factors in corn are expressed at various stages during the life of the individual, as, for example, in defective seeds Jones (38), in white seedlings Emerson (31), Lindstrom (51), Demerec (26), etc. It has not been possible to demonstrate conclusively that such factors occur in fungi, and while they may not be responsible for the germination failure of some of the basidiospores of the Corticium under investigation or of growth failure of others after germination, and of the inability of still others to produce spores after apparently normal growth, yet the wide use of such theoretical factors in explaining certain phenomena must be acknowledged.

Heterothallism. It might be assumed that the reason for the nonspore-forming character of some single-spore isolations lies in the fact that the fungus is heterothallic and the spores, having a haploid consituation, do not form basidiospores. The results obtained from the preliminary matching experiments seemed to indicate such to be the case. Yet the failure to confirm these results in a clear-cut manner after repeated experimental efforts seems to indicate that basidiospore formation in this fungus is not the result of the union of sexual strains.

Further grounds for this belief are afforded from the negative results obtained from matching nonspore-forming single-spore cultures of unknown ancestry as well as pedigreed cultures isolated by the glass-needle method. These cultures were matched in all possible combinations under what are believed to be optimum conditions, but in no case were basidiospores observed to have been formed.

It might be argued that the point is still to be proved on account of the small number (4) of pedigreed nonspore-forming cultures which were matched. However, the very rare occurrence of these infertile forms would seem strong evidence to indicate that infertility is the exception rather than the rule in the Corticium under consideration.

The fact that all of the single-spore cultures isolated from the fertile single-spore culture $B6_2$ formed basidiospores (Table 11) might be considered further proof that the fungus is normally homothallic. In the case of a heterothallic fungus it is assumed that all of the spores isolated from a given basidium will have a haploid constitution, and that no single-spore culture will form spores until a union occurs between its mycelium and that of the sexually opposite form. *In no case in the present investigation was more than one nonspore-forming single-spore culture isolated from a single basidium regardless of whether it bore two, three, or four basidiospores.* This is shown in table 10, and only four cases occurred out of the 31 sets from individual basidia. In two of these cases one basidiospore was infertile, while another, isolated from the same basidium, was fertile.

It seems to be more reasonable to assume that the sterile character of some of the single-spore cultures is not due to complicated sex factors, as reported by Hanna (35) for *Coprinus lagopus*, but that it is due to some factor which has suppressed the spore-forming propensity of the fungus and has permitted only vegetative growth. It has been shown that various external factors, such as quality of food, humidity, and temperature, are controlling factors in the basidiospore formation in form R-40. However, such external factors cannot be considered responsible for the failure of some of the cultures to form basidiospores because all were grown under optimum conditions for reproduction in this fungus. The possibility of internal limiting factors is advanced. From the evidence presented it may be assumed that the original culture of R-40 is in an unstable condition, since it yields both fertile and sterile cultures as compared to the single-spore culture $B6_2$ which may be considered stable, since all of its progeny have formed spores. Just as $B6_2$ may be considered stable for spore formation, so the nonspore-forming cultures may be considered stable for nonspore-formation. Whether a single-spore culture will be fertile or sterile will depend on whether the internal factors for spore formation or for vegetative growth have the upper hand. The great variation in spore-forming capacity exhibited by the single-spore cultures of $B6_2$, some forming basidiospores abundantly, while others, scarcely any at all, seems to show that there are some grounds for the hypothesis that unknown internal factors govern basidiospore formation in the fungus studied. Whether a cytological study of nuclear behavior in the basidium will supply the answer remains to be determined.

Mutations. Mutations,[15] saltations, or aberrant forms in fungi have been reported by Blakeslee (7) in Mucor, Christensen (21), and Stevens

[15] The term "mutation" is here used not in the de Vriesian sense but rather loosely as referring to a sudden change from the parent form not necessarily so stable as to segregate out according to Mendelian principles.

(78) in Helminthosporium, Bonar (8) in Brachysporium, by Leonian (50) in Phytophthora, and by Caldis and Coons (19) in Cladosporium. These mutations found expression in various ways, such as reduced growth, lack of conidia, loss of color, pathogenicity, etc. In fact, it appears that something was lost in all of these aberrant forms. When considered from this viewpoint, the apparently abnormal sterile cultures may be considered as mutations from the normal spore-forming character of the fungus, having lost the faculty of forming basidiospores.

A mutation characterized by loss of the power of forming basidiospores seems to have occurred in a subculture made from the original spore-forming Rhizoctonia R-40. At no time had subcultures from this source failed to form basidiospores when grown under favorable conditions. During the spring and summer of 1926 in the subculture, from which the aberrant culture arose, basidiospores had formed normally and had been used as a source of inoculum for petri-dish cultures used for single-spore isolation work. After July of that year no further transfers were made until September 20, when work was resumed. Transfers made at that time yielded only mycelial and sclerotial growth. Numerous transfers made at short intervals in an attempt to reinvigorate the fungus failed to restore its original spore-forming condition. The Klebsian method of growing organisms, first in media rich in food materials to obtain abundant vegetative growth and then transferring them to media poor in food content to induce reproduction, was tried. The aberrant culture was grown in flasks of malt-extract broth and after a mat of mycelium had formed over the surface of the medium, portions of it were transferred to test tubes containing a sterile filter paper saturated with sterile distilled water. Two weeks later a microscopic examination showed no basidiospores. The checks used in these trials, a transfer from an old subculture of the fungus made nine months earlier, and a transfer from the spore-forming single-spore culture $B6_2$, formed basidiospores abundantly.

That reversibility of mutating forms of fungi is possible has been pointed out by Blakeslee (7), Leonian (50), and by Caldis and Coons (19). That the aberrant form of R-40 has not entirely lost the function of spore formation and that it may possibly revert to its former condition are shown by the fact that when grown on agar containing either maltose or malt extract, as sole source of food or stimulants, the culture did form a few scattered groups of hymenial cells and basidia. These were found by means of the microscope amongst the masses of sclerotial cells on the top plate of the petri-dish culture.

The behavior of this aberrant culture shows that some internal factor has swung the balance from its normal spore-forming condition to that which encourages only mycelial and sclerotial development. The neutrali-

zation or elimination of this factor would probably permit the return of the fungus to its original condition.

The abnormal culture referred to above is strikingly similar in behavior to the hitherto sterile culture, R-43, isolated from the original mass of hymenial material in 1924. This culture, which was observed to have formed basidiospores during 1924, 1925, and 1926 *only when grown in association with other sterile cultures* and then in only a few instances, was discovered in March, 1927, to have formed a few basidia and spores when grown alone. The previous growth on malt extract and subsequent transfer to Coons' synthetic medium in a petri dish are thought to have either stimulated the latent spore-forming factor of the fungus or disturbed an inhibiting factor, so that a few basidiospores resulted. The latter were discovered while making a critical microscopic examination of the culture. It is believed that by growing this culture in association with other infertile cultures a similar stimulation occurred which resulted in the formation of a few basidiospores. This reaction is not considered to be of a genetic nature.

DISCUSSION

I

A Rhizoctonia has been isolated which appears to be vastly different from the forms usually observed. Whereas, the common experience has been that known forms of Rhizoctonia remain sterile in culture, this new form is fertile and forms hymenial cells, basidia, and spores abundantly when grown under certain environmental conditions. It is to be called **Corticium praticola,** sp. nov.

The vegetative characters of *C. praticola* and of *C. vagum* B. & C., as obtained in culture, are similar in many respects. The mycelium is characterized by a uniform diameter, smooth wall, and constrictions where branching occurs. Further, as described by Duggar and Stewart (29) for *C. vagum,* a septum is present very near the constriction. Anastomoses are abundant. The sclerotia, while not so large nor so numerous as those of *C. vagum,* are similar to those of the latter both as young cells and as fully developed sclerotia. (Fig. 5, B.) These similarities indicate that the fungus under consideration, in its vegetative stage, is unquestionably a Rhizoctonia.

Although many similarities exist in the vegetative growth of *Corticium praticola* and that of *C. vagum,* some differences are apparent. The most striking one is the hyaline or white character of the mycelium of the new species as contrasted with the brown color associated with *C. vagum.* Specific morphological differences occur in the perfect stages of the two species, such as differences in size of basidiospores as well as the number of spores

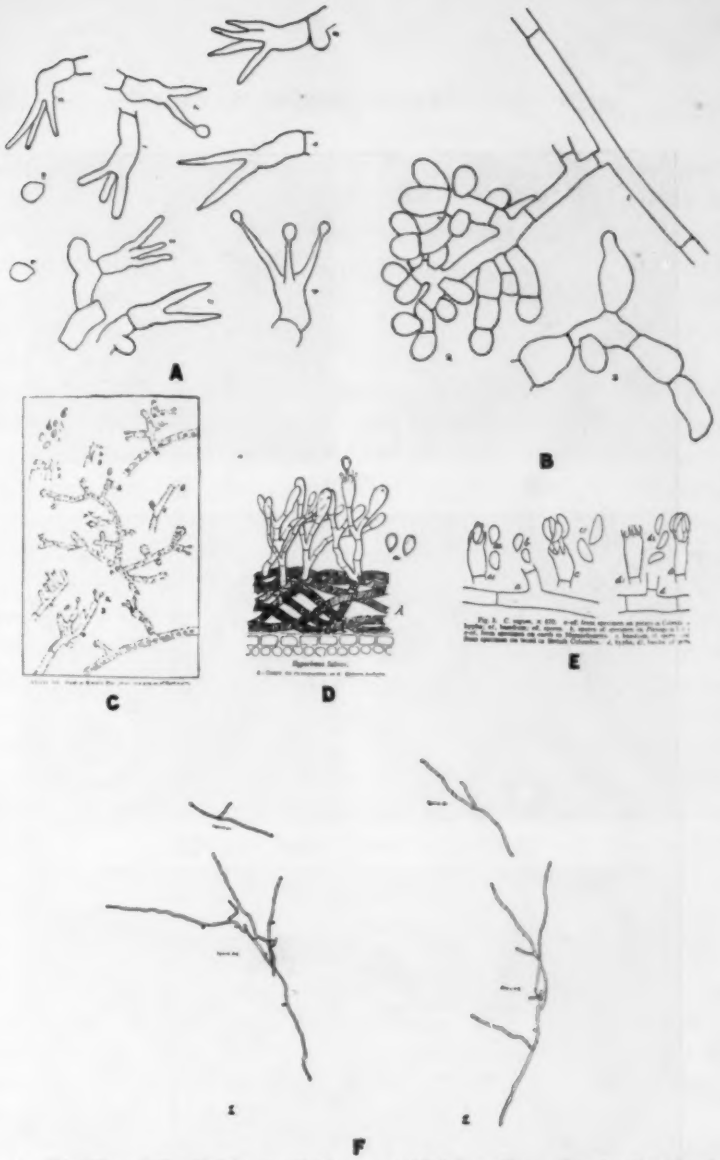


FIG. 5. A. Basidia of *Corticium praticola* on artificial media. Camera lucida drawings, Bausch & Lomb objective 3 mm., ocular 10.

Figs. 1–4. Immature basidia. Figs. 5–8. Mature basidia, spores discharged. Figs. 9–10. Mature basidiospores.

B. *C. praticola* on artificial medium. Camera lucida drawings.

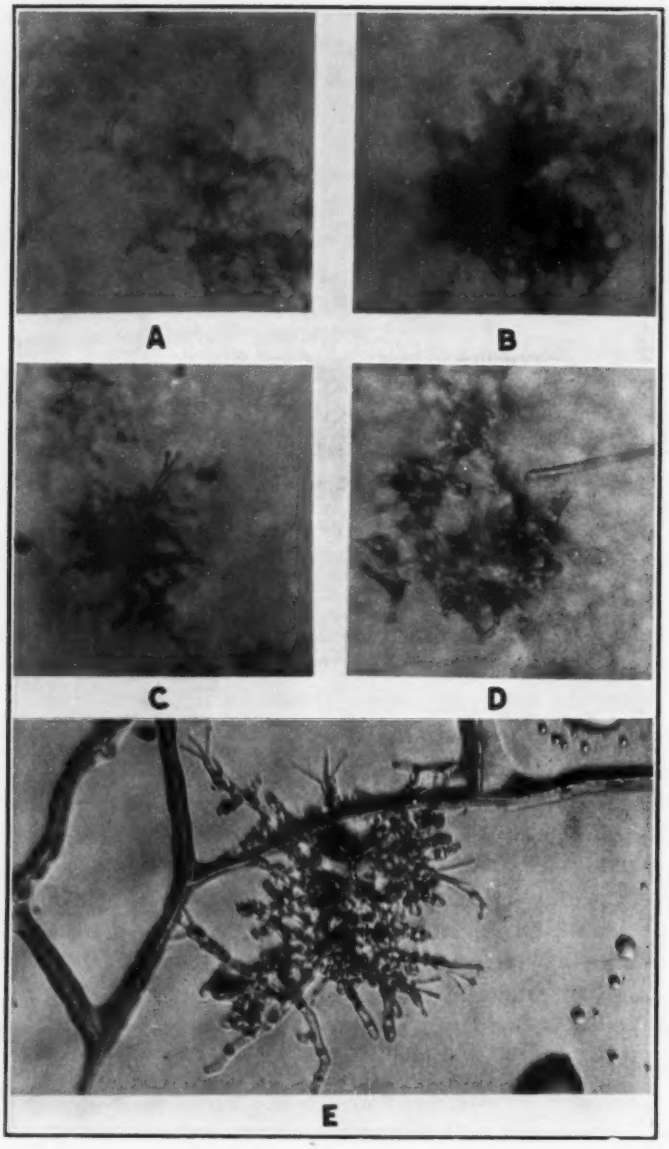
Fig. 1. Vegetative hypha. Fig. 2. Hymenial cells. Fig. 3. Sclerotial cells.

C. *Corticium vagum* B. & C. from Rolfs (71). D. *Hypochnus solani* Prill. & Delacr. from Prillieux and Delacroix (64). *E. Corticium vagum* B. & C. from Burt (17).

F. Isolation of single spores.

Fig. 1. Two spores isolated from basidium No. 62, showing difference in rate of growth. Camera lucida drawing made 48 hours after isolation of basidiospores. B. & L. objective 16 mm., ocular 10.

Fig. 2. Two basidiospores isolated from basidium No. 59, showing similar difference in rate of growth.



Photomicrographs of *C. praticola.* (Enlarged.)

FIG. 6. A. Basidium, near surface of medium in petri dish; two basidiospores.
B. Basidium with three spores.
C. Basidium with four spores.
D. Isolation of single spores. Note basidiospore attached to side of needle adjacent to sterigma from which it was removed.
E. *C. praticola* on under surface of top plate of petri dish, showing prevalence of basidia bearing three basidiospores.

formed by each basidium and differences in lengths of sterigmata. According to Burt (18) the number of basidiospores formed on each basidium of *Corticium vagum* (*R. solani* Kühn) varies from 4 to 6, while in *C. praticola* the basidiospores vary in number from 1 to 4 on each basidium, three being the number most frequently observed. (Fig. 6, E.) The smaller spore size and the unusual length of the sterigmata of *C. praticola* are also thought to be significant.

It should be pointed out that these comparisons are made between the perfect stages of two fungi, one of which developed on artificial media, the other under natural conditions on natural hosts. It is perhaps unfortunate that the cultures of *C. vagum* to which *C. praticola* was compared in its vegetative stages did not form the perfect stage in culture so that a comparison of basidia of exactly similar origin could be made between the two forms. However, Müller (59) found that the perfect stage of *C. vagum* (*H. solani*) which he obtained under artificial conditions was not strikingly different from descriptions given in the literature. It would seem unlikely, therefore, that the perfect stage of *C. vagum* on artificial media would be much different than on its natural hosts. No differences of basidial form or structure attributable to place of origin were found in *Corticium praticola*. When cultured on alfalfa seedlings kept under very humid conditions, the perfect stage was obtained. Microscopic examination and measurement of the hymenial cells, basidia, sterigmata, and basidiospores showed them to be the same as similar structures of the fungus formed on artificial media.

II

The present study has shown the important rôle played by external factors during reproduction in *C. praticola* and has demonstrated that in the environmental complex there are certain factors on the presence of which reproduction is dependent. It has shown further that these factors must be present in certain intensities for optimum reproduction.

Humidity, temperature, and aeration were found to be controlling factors. Light appeared to encourage spore formation, whereas reaction of substratum, in the intensities tried, was found to have no effect upon either growth or reproduction.

Of all of the contributing external factors, that of humidity, influencing probably the transpiration of the fungus, seemed to be most important. This was the controlling factor when all other conditions were favorable for reproduction. Too low humidity prevented basidiospore formation; whereas, too great an intensity retarded the phenomenon. Optimum basidiospore formation occurred at approximately 60 per cent humidity. It is noteworthy that the occurrence of *Corticium vagum* in nature has also been correlated with abundant moisture.

Temperature also was found to be a controlling factor. Although basidiospore formation occurred over a considerable range of temperature (16.0° to 24.3° C.), the optimum appeared to be about 20.0° C. Vegetation was found to have a wider range than reproduction. Similar results were reported by Klebs (43), Coons (22), and others. The temperature studies showed that sclerotium formation and that of basidiospores are opposed to each other. The optimum temperature for the former was very close to the inhibiting point for the latter.

Oxygen was found necessary for the growth as well as for reproduction of the fungus concerned. Aeration of cultures was found to encourage basidiospore formation, while too great an oxygen tension was inhibitive.

Light was not found to be an essential factor in reproduction but seemed to favor it. Whether the increase in the number of basidiospores formed in the light was due to an oxidation response, as reported by Coons (22), was not determined. The studies on the effect of light gave further proof that sclerotium and basidiospore formation are opposed to each other. Sclerotia were formed only in those cultures which were kept in the dark. In other experiments it was found that conditions unfavorable to the formation of basidiospores usually were favorable for the formation of sclerotia.

The reaction of the substratum, a controlling factor for the growth and reproduction of many organisms, was found to have no effect on basidiospore formation of the Corticium under consideration.

III

Just as certain external factors were found to be controlling factors in basidiospore formation, so too it seems that internal or genetic factors exert a similar influence.

It has been shown that some single-spore isolation of *Corticium praticola* remained sterile when grown under conditions which resulted in abundant formation of basidiospores in others. The failure to form spores is thought to be due to some inherited factor which does not respond to the stimuli exerted by the external complex.

Sterility in organisms has been shown in many cases to be due to the segregation of sex factors. Some grounds for the belief that heterothallism existed in the fungus under consideration were obtained in the early part of the investigation. Basidiospores were obtained when two previously sterile cultures were grown together. A few confirmatory results also were obtained, adding more weight to the supposition. However, the spore formation in these cases was always meager and not abundant as was the case in the fertile cultures. By a study of single-spore cultures obtained from individual basidia of a fertile form the true nature of the fungus was learned. In the absence of heterothallism, it is concluded that the fungus

is homothallic, since all of the pedigreed single-spore forms, with only four exceptions, have formed basidiospores. All of these fertile cultures behaved alike irrespective of whether they had their origin on a 2-, 3-, or 4-spore basidium.

That the sterility of some of the pedigreed single-spore forms, as well as those of unknown origin, is not due to a haploid genetic constitution is indicated by their failure to form basidiospores when grown together in all possible combinations. The fact that all of the progeny of one single-spore isolation ($B6_2$) were fertile indicates that the situation here is apparently not analogous to that found in heterothallic forms and that some internal factor other than sex is responsible for the sterility of the cultures referred to above.

The presence of some factor in *Corticium praticola* which affects spore formation is shown by the behavior of the progeny of the single-spore isolation $B6_2$ referred to in the foregoing. Some of these cultures formed basidiospores very abundantly, while others, grown under similar environment, formed scarcely any at all. Further proof of the existence of such controlling internal factors was obtained from the abnormal culture which reverted from the spore-forming to sterile condition. The function of spore formation is not lost in this aberrant culture but is merely suppressed, as was shown by causing it to form a few basidiospores when grown under certain conditions.

It is believed that similar internal factors are operating in the case of the apparently sterile form R-43, isolated from the original mass of hymenial material in 1924. These factors were sufficiently overcome in the spring of 1927 so that the culture formed a few basidiospores when grown alone. It is thought that growing the apparently sterile form in association with other infertile cultures had a similar stimulative effect on the internal condition of this fungus.

SUMMARY

1. The "Rhizoctonia problem" has been approached from an entirely new angle: (a) by the discovery of a new species which was more easily subjected to study than the hitherto known forms, (b) by the application of the more modern technique in the determination of its biological characteristics.

2. This Rhizoctonia forms the perfect stage, which shows that it belongs to the Basidiomycetes and that it is a Corticium.

3. The hymenial stage has been regularly developed in culture on artificial media and on inoculated alfalfa plants. From the latter the fungus was reisolated and found to have retained its ability to produce basidiospores.

4. The effect of external factors of the environment on the formation of the hymenium and basidiospores has been determined. It is found that humidity, oxygen, and temperature are controlling factors. Light, although a contributing factor for optimum basidiospore formation, is to be considered of secondary value. The reaction of the medium had no influence under the conditions to which the cultures were subjected. The most favorable food supply consisted in a medium composed of malt extract and maltose supplemented with potassium dihydrogen phosphate, calcium nitrate, and magnesium sulphate.

5. An analysis by means of single-spore cultures, to determine the sexual conditions present in each of the basidiospores of any one basidium, has convinced the author that this Corticium is homothallic.

6. The discovery of a sterile form of this species, derived from the same source as several fertile ones, led to a detailed study of single-spore generations of both the fertile and sterile forms, to determine whether the causes were genetic or due to unfavorable conditions.

7. The sterile condition of the form which did not produce basidiospores was found to be unaffected by varying the external factors, and it was concluded that such cultures arose from internal disturbances in the mycelium.

8. An analysis of the sterile versus the fertile forms also showed that the sterility was not associated with sex factors.

9. The new plant is considered to belong to the genus Corticium and the name **Corticium praticola**, sp. nov. is proposed for it.

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LITERATURE CITED

1. ATKINSON, G. F. Some diseases of cotton. IV. "Sore-shin," "damping off," "seedling rot." Ala. Agr. Exp. Sta. Bul. 41: 30–39. 1892.
2. ————————. Damping off. N. Y. (Cornell) Agr. Exp. Sta. Bul. 94. 1895.
3. BARBER, M. A. The pipette method in the isolation of single microorganisms and the inoculation of substances into living cells. Philip. Jour. Sci. Sec. B. Trop. Med. 9: 307–360. 1914.
4. BAUR, E. Einführung in die experimentelle Vererbungslehre. 5. u. 6. Aufl., 436 p. Gebrüder Borntraeger, Berlin, 1922.
5. BENSAUDE, M. Recherches sur le cycle évolutif et la sexualité chez les Basidiomycètes. 156 p. H. Bouloy, Nemours. 1918. (Thesis, Univ. Paris.)
6. BLAKESLEE, A. F. Sexual reproduction in the *Mucorineae*. Amer. Acad. Arts and Sci. Proc. 40: 203–320. 1904.
7. ————————. Mutation in *Mucors*. Jour. Hered. 11: 278–284. 1920.
8. BONAR, LEE. Studies on the biology of *Brachysporium trifolii*. Amer. Jour. Bot. 11: 123–158. 1924.
9. BRITON-JONES, H. R. Strains of *Rhizoctonia solani* Kühn (*Corticium vagum* Berk. & Curt.). Trans. Brit. Mycol. Soc. 9: 200–210. 1924.

10. ————. Mycological work in Egypt during the period 1920–1922. Min. Agr. Egypt Tech. & Sci. Serv. Bul. 49. 1925.
11. BUDDIN, W., and E. M. WAKEFIELD. Some observations on the growth of *Rhizoctonia crocorum* (Pers.) DC. in pure culture. Ann. Appl. Biol. 11: 292–309. 1924.
12. ————, ————. Studies on *Rhizoctonia crocorum* (Pers.) DC. and *Helicobasidium purpureum* (Tul.) Pat. Trans. Brit. Mycol. Soc. 12: 116–140. 1927.
13. ————, ————. Further notes on the connection between *Rhizoctonia crocorum* and *Helicobasidium purpureum*. Trans. Brit. Mycol. Soc. 14: 97–99. 1929.
14. BULLER, A. H. R. Experiments on sex in mushrooms and toadstools. Nature 114: 826. 1924.
15. ————. Researches on Fungi. v. 2. Longmans, Green & Co., London, New York, etc. 1922.
16. BURT, E. A. The *Thelephoraceae* of North America I. Ann. Mo. Bot. Gard. 1: 185–228. 1914.
17. ————. The *Thelephoraceae* of North America. IV. Ann. Mo. Bot. Gard. 3: 203–241. 1916.
18. ————. The *Thelephoraceae* of North America. XV. Ann. Mo. Bot. Gard. 13: 173–354. 1926.
19. CALDIS, P. D., and G. H. COONS. Achromatic variations in pathogenic fungi. Papers Mich. Acad. Sci. 6: 189–236. 1927.
20. CHAMBERS, R. A simple apparatus for micro-manipulation under the highest magnifications of the microscope. Sci. NS. 54: 411–413. 1921.
21. CHRISTENSEN, J. J. Physiologic specialization and mutation in *Helminthosporium sativum*. Phytopath. 15: 785–795. 1925.
22. COONS, G. H. Factors involved in the growth and the pycnidium formation of *Plenodomus fuscomaculans*. Jour. Agr. Res. 5: 713–769. 1916.
23. CRAIGIE, J. H. Heterothallism in the rust fungi. (Abstr.) Phytopath. 18: 147. 1928.
24. CUÉNOT, L. L'hérédité chez les souris. Vehr. Naturf. Verein. Brünn 49: 214–222. 1911.
25. DANA, B. F. The *Rhizoctonia* disease of potatoes. Wash. Agr. Exp. Sta. Bul. (Tech. Paper) 191. 1925.
26. DEMEREC, M. Inheritance of white seedlings in maize. Genetics 8: 561–585. 1923.
27. DODGE, B. O. Nuclear phenomena associated with heterothallism and homothallism in the ascomycete *Neurospora*. Jour. Agr. Res. 35: 289–305. 1927.
28. DUGGAR, B. M. *Rhizoctonia crocorum* (Pers.) DC. and *Rhizoctonia solani* Kühn (*Corticium vagum* B. & C.) with notes on other species. Ann. Mo. Bot. Gard. 2: 403–458. 1915.
29. ————, and F. C. STEWART. The sterile fungus *Rhizoctonia* as a cause of plant diseases in America. N. Y. (Cornell) Agr. Exp. Sta. Bul. 186. 1901.
30. DUHAMEL DU MONCEAU, H. L. Explication physique d'une maladie qui fait périr plusieurs plantes. . . . Mem. Acad. Sci. Paris. 1728: 100–112. 1753.
31. EMERSON, R. A. The inheritance of certain "abnormalities" in maize. Ann. Rpt. Amer. Breeders' Assoc. 8: 385–399. 1912.
32. ENGLER, A., and K. PRANTL. Die natürlichen Pflanzenfamilien. Teil 1, Abt. 1**. 1900.

33. GILLESPIE, L. J. The growth of the potato scab organism at various hydrogen-ion concentrations as related to the comparative freedom of acid soils from the potato scab. Phytopath. 8: 257–269. 1918.
34. GRATZ, L. O. Wire stem of cabbage. N. Y. (Cornell) Agr. Exp. Sta. Mem. 85: 1925.
35. HANNA, W. F. The problem of sex in *Coprinus lagopus*. Ann. Bot. 39: 431–457. 1925.
36. ————. The dry-needle method of making monosporous cultures of Hymenomycetes and other fungi. Ann. Bot. 38: 791–795. 1924.
37. JOCHEMS, S. C. J. Rhizoctonia-ziekten ob tabak in Deli. Deli Proefsta. Medan-Sumatra. Bul. 21. 1926.
38. JONES, D. F. Heritable characters of maize, IV. A lethal factor—defective seeds. Jour. Hered. 11: 161–167. 1920.
39. KAUFFMAN, C. H. A contribution to the physiology of the *Saprolegniaceae*, with special reference to the variations of the sexual organs. Ann. Bot. 22: 361–387. 1908.
40. KLEBS, G. Die Bedingungen der Fortpflanzung bei einigen Algen und Pilzen. 543 p. G. Fischer, Jena, 1896.
41. ————. Zur Physiologie der Fortpflanzung einiger Pilze. I. *Sporodinia grandis* Link. Jahrb. Wiss. Bot. 32: 1–70. 1898.
42. ————. Zur Physiologie der Fortpflanzung einiger Pilze. II. *Saprolegnia mixta* De Bary. Jahrb. Wiss. Bot. 33: 513–593. 1899.
43. ————. Zur Physiologie der Fortpflanzung einiger Pilze. III. Algemeine Betrachtungen. Jahrb. Wiss. Bot. 35: 80–203. 1900.
44. ————. Über *Sporodinia grandis*. Bot. Zeit. 60 (II): 176–199. 1902.
45. KNIEP, H. Über morphologische und physiologische Geschlechtsdifferenzierung. Verhandl. Physikal.- Med. Gesell. Würzburg, n. F. 46: 1–18. 1920.
46. ————. Untersuchungen über den Antherenbrand (*Ustilago violacea* Pers.). Zeitschr. Bot. 11: 257–284. 1919.
47. KOTILA, J. E. Concerning a Rhizoctonia which forms hymenial cells and basidiospores in culture. Sci. N. S. 67: 490. 1928.
48. KÜHN, J. Die Krankheiten der Culturgewächse, ihre Ursachen und ihre Verhütung. 312 p. Berlin, Bosselmann, 1858.
49. LEONIAN, L. H. A study of factors promoting pycnidium formation in some Sphaeropsidales. Amer. Jour. Bot. 11: 19–50. 1924.
50. ————. Physiological studies on the genus Phytophthora. Amer. Jour. Bot. 12: 444–498. 1925.
51. LINDSTROM, E. W. Chlorophyll inheritance in maize. N. Y. (Cornell) Agr. Exp. Sta. Mem. 13. 1918.
52. LITTLE, C. C. Experimental studies of the inheritance of color in mice. 92 p. Carnegie Inst., Wash., 1913. (Pub. 179).
53. MATSUMOTO, T. Studies in the physiology of fungi XII. Physiological specialization in *Rhizoctonia solani* Kühn. Ann. Mo. Bot. Gard. 8: 1–62. 1921.
54. MATZ, J. The Rhizoctonias of Porto Rico. Jour. Dept. Agr. Porto Rico 5: 1–30. 1921.
55. MEER, J. H. H. VAN DER. Rhizoctonia- en Olpidium-aantasting van bloemkoolplanten. Tijdschr. Plantenziekten 32: 209–242. 1926.
56. MORGAN, T. H., and C. B. BRIDGES. Sex-linked inheritance in Drosophila. 87 p. Carnegie Inst., Wash., 1916. (Pub. 237).
57. MOUNCE, I. Homothallism and heterothallism in the genus *Coprinus*. Trans. Brit. Mycol. Soc. 7: 256–269. 1922.

58. MÜLLER, K. O. Über die Beziehungen zwischen *Rhizoctonia solani* Kühn und *Hypochnus solani* Prill. et Del. Arb. Biol. Reichanst. Land.- u. Forstw. 11: 326–330. 1923.

59. ————. Untersuchungen zur Entwicklungsgeschichte und Biologie von *Hypochnus solani* P. u. D. (*Rhizoctonia solani* K.). Arb. Biol. Reichanst. Land.- u. Forstw. 13: 197–262. 1924.

60. NEWTON, D. E. The distribution of spores of diverse sex on the hymenium of *Coprinus lagopus*. Ann. Bot. 40: 891–917. 1926.

61. NOVY, F. G., H. R. ROEHM, and M. H. SOULE. Microbic Respiration I. The compensation manometer and other means for the study of microbic respiration. Jour. Infect. Dis. 36: 109–167. 1925.

62. PELTIER, G. L. Parasitic rhizoctonias in America. Ill. Agr. Exp. Sta. Bul. 189. 1916.

63. PETHYBRIDGE, G. H. Investigations on potato diseases. V. "Black speck" scab and "collar fungus." Dept. Agr. and Techn. Instr. Ireland Jour. 15: 513–517. 1915.

64. PRILLIEUX, E., and G. DELACROIX. *Hypochnus solani* nov. sp. Soc. Mycol. France Bul. 7: 220–221. 1891.

65. RAEDER, J. M., C. W. HUNGERFORD, and N. CHAPMAN. Seed treatment control of Rhizoctonia in Idaho. Idaho Agr. Exp. Sta. Res. Bul. 4. 1925.

66. RICHARDS, B. L. Pathogenicity of *Corticium vagum* on the potato as affected by soil temperature. Jour. Agr. Res. 21: 459–482. 1921.

67. ————. Further studies on the pathogenicity of *Corticium vagum* on the potato as affected by soil temperature. Jour. Agr. Res. 23: 761–770. 1923.

68. ————. Soil temperature as a factor affecting the pathogenicity of *Corticium vagum* on the pea and the bean. Jour. Agr. Res. 25: 431–449. 1923.

69. RIEHM, E. Über den Zusammenhang zwischen *Rhizoctonia solani* Kühn und *Hypochnus solani* Prill. u. Del. K. Biol. Anstalt. Land.- u. Forstw. Mitt. 11 (Ber. 6) 23. 1911.

70. ROLFS, F. M. Potato failures. A preliminary report. Colo. Agr. Exp. Sta. Bul. 70. 1902.

71. ————. Potato failures. A second report. Colo. Agr. Exp. Sta. Bul. 91. 1904.

72. ————. *Corticium vagum* B. & C. var. *solani* Burt. Sci. N. S. 18: 729. 1903.

73. SACCARDO, P. A. Sylloge fungorum. v. II. Patavii. 1895.

74. SHAW, F. J. F. The morphology and parasitism of Rhizoctonia. Dept. Agr. India Mem. Bot. Ser. 4: 115–153. 1912.

75. SHEAR, C. L., and B. O. DODGE. Life histories and heterothallism of the red bread-mold fungi of the *Monilia sitophila* group. Jour. Agr. Res. 34: 1019–1042. 1927.

76. SHULL, G. H. A peculiar negative correlation in Oenothera hybrids. Jour. Genetics 4: 83–102. 1914.

77. STAKMAN, E. S., and J. J. CHRISTENSEN. Heterothallism in *Ustilago zeae*. Phytopath. 17: 827–834. 1927.

78. STEVENS, F. L. The Helminthosporium foot rot of wheat, with observations on the morphology of *Helminthosporium* and on the occurrence of saltation in the genus. Bull. Ill. Nat. Hist. Surv. 14: 78–184. 1922.

79. THOMAS, K. S. Onderzoekingen over *Rhizoctonia*. 97 p. Electr. Druk. "De Industrie" J. van Druten, Utrecht, 1925.

EXPERIMENTS WITH BLUESTAIN FUNGI IN SOUTHERN PINES

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ASSOCIATION OF BLUESTAIN WITH BARK BEETLES

The close association between bluestain and bark beetles in living trees has long been known. Von Schrenk (6) described the death of a large number of western yellow pines, *Pinus ponderosa* Laws., in the Black Hills and stated that wood of trees attacked by the Black Hills beetle, *Dendroctonus ponderosae* Hopk., became stained within a few weeks by a species of Ceratostomella. Münch (5) and MacCallum (4) also have reported the occurrence of bluestain in conifers attacked by bark beetles. Craighead (2) has mentioned their invariable association with Dendroctonus attack and has suggested that the fungi play an important rôle in the death of beetle-attacked trees. It was largely through his stimulating interest that this joint study was begun.

Bluestain in southern pines, except in association with beetle attack, is uncommon, although it is occasionally found in pines which have been severely wounded, such as in dry faces of turpentined trees. In Sweden (3) spruce trees which have been blazed and left standing for several years are frequently reported stained. Colley and Person (1) have found that of 234 zones of bluestain in western yellow pines only 4 per cent appeared not to have originated from entrance holes of the western pine beetle, *Dendroctonus brevicomis* Lec. Of 218 zones of bluestain in shortleaf pine, *Pinus echinata* Mill., attacked by the southern pine beetle, *Dendroctonus frontalis* Zimm., the writers found 97 per cent directly associated with the entrance holes of the beetle.

The circumstantial evidence presented above suggests that the bark beetles carry the bluestain fungi into their tunnels and thereby inoculate the trees.

INSECTS ASSOCIATED WITH BLUESTAIN

The following discussion deals briefly with the life history and habits of the bark beetles included in this preliminary study.

The southern pine beetle is the most destructive insect enemy of pines in the Southern States. It attacks pines of all the species that occur within its range. The adult insect is a small, brownish or blackish beetle, about one-eighth inch long. It attacks the central and upper portions of healthy pine trees, weakened individuals, and occasionally freshly felled logs. The beetles bore through the bark and excavate long serpentine galleries which may run in any direction and which extend through the inner layers of the

bark and mark the surface of the wood. Eggs are laid in small niches along the galleries and the young bore away from the galleries about one-half inch during the course of their development. The tunneling of the adults, therefore, and not that of the young, has in the past been held largely responsible for the death of the trees, because fading of the foliage occurs before the larvae are half grown.

One of the engraver beetles, *Ips calligraphus* Germ., usually considered of secondary importance, sometimes attacks healthy trees. It is usually found associated with the southern pine beetle, but confines its activities to those parts of the trees not occupied by other species of insects. The adult galleries are usually perpendicular, but often branch in many directions.

The black turpentine beetle, *Dendroctonus terebrans* Oliv., may be found on pines throughout the South. It attacks logs, stumps, and occasionally the bases of green trees. Seldom, if ever, is it able to establish itself in large numbers, because the individuals are usually "pitched out." Adult galleries extend in a vertical direction and, therefore, do not girdle the trees. This beetle, because of its habits, can inoculate only a relatively small part of the tree with bluestain. The two other beetles may attack almost any part of the boles of trees in large numbers and are, therefore, more capable agents of inoculation.

A number of other species of bark beetles are associated both with dying pines and with bluestain, but the experimental inoculations here described were made only with stain fungi isolated from trees attacked by the three above-named beetles.

METHODS

The object of the experiments here reported was to determine the ability of bluestain fungi to cause death of trees independent of beetle attack. Isolations were made from the blue wood of trees attacked by bark beetles and also from adult beetles. In a few cases bluestain fungi were obtained from adult beetles taken from newly made tunnels without a sign of stain. The preliminary study indicates that the isolated fungi consist of several species or strains of Ceratostomella or very closely related fungi. The stain fungi associated with the engraver beetles as a group, the turpentine beetles, and the southern pine beetles can be distinguished readily from each other in culture.

Pitch pines, *Pinus rigida* Mill., and shortleaf pines, *Pinus echinata* Mill., 4 to 8 inches in diameter, breast high, were selected at random on the Bent Creek Experimental Forest near Asheville, N. C., and inoculated with staining fungi isolated from blued wood of trees attacked respectively by *Dendroctonus frontalis, D. terebrans,* and *Ips calligraphus.*

The three types of organisms were grown in Kolle flasks on rice which had been boiled to a mid-soft consistency and then autoclaved for 20 minutes at 15 pounds pressure. With this material each tree in the first group (Table 1) was inoculated with 5 to 9 poultices arranged obliquely one above

TABLE 1.—*Results of inoculating southern pines with fungi isolated from bluestained wood of trees attacked by bark beetles*

Culture no.	Species of pine inoculated	Method of inoculation	No. of places inoculated[1]	Sources of inoculum; from tree attacked by	Weeks after inoculation	Condition of tree
12	*Pinus rigida*	Poultice	5	*D. terebrans*	8	Dead
	do.	do.	5	Check (sterile rice)	20	Live
6	do.	do.	5	*I. calligraphus*	20	do.
6	*P. echinata*	do.	5	do.	20	do.
14	do.	do.	9	*D. frontalis*	10	Dying
14	do.	do.	9	do.	18	Live
6	do.	do.	7	*I. calligraphus*	10	Dying
6	do.	do.	7	do.	10	Dead
12	do.	do.	9	*D. terebrans*	10	do.
32	do.	do.	9	*D. frontalis*	13	do.
32	do.	do.[2]	9	do.	5	do.
32	do.	do.[2]	9	do.	8	do.
14	*P. rigida*	Drill holes	200	*D. frontalis*	21	Live
	do.	do.	200	Check	21	do.
6	*P. echinata*	do.	250	*I. calligraphus*	21	do.
	do.	do.	250	Check	21	do.
14	do.	do.	200	*D. frontalis*	20	do.
11	*P. echinata*	Grease gun	100	*D. frontalis*	14	Dead
11	do.	do.	80	do.	14	do.
11	do.	do.	100	do.	10	do.
11	do.	do.	80	do.	14	do.
11	do.	do.	80	do.	15	do.
11	do.	do.	90	do.	14	Live
11	do.	do.	80	Check	13	do.
11	*P. rigida*	do.	90	*D. frontalis*	13	Dead
32	do.	do.	60	do.	13	do.

[1] Number of grease-gun and drill-hole inoculations approximate.

[2] Poulticed every 2 feet for 18 feet. Each poultice girdled the tree.

the other in an ascending spiral, in such manner as to girdle the tree at least once in approximately a 6-foot length of bole. The bark, in rectangular patches, about 3 by 5 inches in size, was cut through to the wood and removed, a rice-fungus poultice applied to the exposed surface and the bark patches fastened with nails. The second group of trees was inoculated through small drill holes bored through the bark and usually not more than one-half inch into the sapwood. The 200 to 250 holes in each tree were spaced about 4 inches apart, both vertically and horizontally, and were dis-

tributed over a 15- to 20-foot length of bole. The inoculum for this second group, grown on malt-extract agar, was introduced into the holes with a small piece of wood. In the third group the organism, grown on rice, was forcibly introduced tangentially into the cambium region by means of an automobile grease gun fitted with a slender copper point. The result was a tangential elliptical pocket usually not more than one square inch in area. From 60 to 100 inoculations were made in each tree, encircling the bole, and extending upwards about 15 feet. In general, this is the part of the bole attacked by *Dendroctonus frontalis*.

EXPERIMENTAL RESULTS

So far as has been observed, there has been a heavy staining of the wood beneath each poultice and beneath almost every grease-gun inoculation. Grease-gun inoculations, from which the stain did not spread, were generally on the lower part of the bole. Here the moisture content of the wood may have been sufficiently high to inhibit growth of the organism. A large number of the points inoculated through drill holes remained unstained, although the percentage has not been determined.

The stain spreads from the point of inoculation chiefly in a radial and longitudinal direction. Beneath poultices it may penetrate an inch or more radially and several inches longitudinally in a week's time. It appears that if inoculations are so made that all the strands of water-conducting elements pass through stained zones at some point the tree will eventually succumb. The vertical extent of the stained portions probably influences the rapidity of death of the inoculated tree.

In the poulticed trees such areas were confined to a rather limited longitudinal distance. Usually a length of not more than 5 or 6 feet of the bole had been inoculated. In the trees inoculated through drill holes a comparatively large volume of the wood remained uninfected because the tangential spread of stain from the straight vertical series of holes was slight. For this reason much stoppage of conduction was not expected. At the time of last examination, the three trees inoculated through drill holes and the two check trees with drill holes appeared to be normal. A much greater amount of inoculum was used in the grease-gun method and, because the 60 to 100 points of inoculation were scattered over a 15-foot length of bole, and favored tangential extension of stain, much stain resulted. In some of the dead trees examined, the entire sapwood was heavily stained for a distance of 10 or 12 feet. The single tree which did not die produced a great quantity of resin at each point of inoculation and only approximately 35 per cent of the volume of sapwood in the region of inoculation was stained.

On beetle-attacked and in inoculated trees mycelium of bluestain fungi grows more abundantly in the medullary rays than in other tissues, although it is by no means confined entirely to the rays. Hyphae are frequently found growing within the lumina of tracheids. Microscopic examination of stained wood shows that the hyphae frequently break down the end walls of the ray parenchyma cells. These cells are usually considered to be the only cells in the xylem which remain alive for a long time after formation and some investigators believe that they have some influence on the conduction of water in living trees. The death of the ray parenchyma through the action of the bluestain fungi may conceivably interfere with the conduction of water.

Bluestained wood in beetle-attacked trees has been ordinarily found by the writers to contain less moisture than unstained portions in the same cross section. The moisture content of trees attacked by bark beetles apparently influences the development of the brood and also influences the growth of the bluestaining fungi. (An examination of the wood of fire-scorched trees, subsequently attacked by the southern pine beetle, showed that the moisture content of the wood was unusually high. It also revealed a much retarded development of bluestain fungi and a decided check of development of the beetle broods.) Bluestain in wood appears to influence the rate of water absorption, for, in a preliminary test on submerged sapwood blocks of shortleaf pine, unstained blocks absorbed rather uniformly an average of 33 per cent of water, based on green weight, as against 29 per cent absorbed by partly-stained blocks and 28 per cent by heavily-stained blocks. The above blocks were approximately of the same size and were cut from the same tree.

Trees in which the southern pine beetle is able to establish itself in large numbers die within a few weeks. The junior writer has severely wounded many pines in many ways. In some cases the bark and cambium have been removed for a distance of several feet; in other cases trees have been girdled by numerous saw cuts or by deep chipping. It has been observed that trees in which the southern pine beetle and accompanying stain fungi are able to establish themselves always die more quickly than mechanically-injured trees.

CONCLUSIONS AND SUMMARY

The writers are of the opinion that the girdling of pines by the tunnels of the southern pine beetles is insufficient to account for the rapid death of attacked trees. The preliminary experiments show that bluestain fungi, together with the wounding which accompanies inoculation, may kill pines in a comparatively short time. It is, therefore, suggested that bluestain organisms may play an important rôle in the death of pines attacked by

the southern pine beetles. Further inoculations with less severe wounding and more numerous controls will be made by the writers.

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LITERATURE CITED

1. COLLEY, R. H., and H. PERSON. Relation between *Dendroctonus* attack and blue-stain infection in *Pinus ponderosa* Laws. (Unpublished manuscript.)
2. CRAIGHEAD, F. C. Interrelation of tree-killing bark-beetles (*Dendroctonus*) and blue stain. Jour. Forestry 26: 836–887. 1928.
3. LAGERBERG, T., G. LUNDBERG, and E. MELIN. Biological and practical researches into blueing in pine and spruce. Svenska Skogsvardsfor. Tidsk. Häft II, 145–272. 1927.
4. MACCALLUM, B. D. Some wood staining fungi. Trans. Br. Myc. Soc. 7: 231–226. 1922.
5. MÜNCH, E. Die Blaufäule des Nadelholzes. Naturwiss. Zeitschr. für Forstu. Landwirtsch. 6: 297–323. 1908.
6. VON SCHRENK, H. The "Blueing" and "Red Rot" of the western yellow pine, with special reference to the Black Hills Forest Reserve. U. S. D. A. Bul. 36. 1903.

A NEW SCLEROSPORA FROM AUSTRALIA

WILLIAM H. WESTON, JR.[1]

In the case of the several known species of Sclerospora such practical questions as their injury to various valuable gramineous crops and their immediate restriction and control necessarily have been the first concern of the plant pathologist. In addition, however, the problem of the original sources of these parasites is one of some interest. In this connection the occurrence of Sclerosporas on wild hosts under natural conditions is of significance.

In February, 1928, Dr. R. J. Noble, Biologist to the Department of Agriculture of New South Wales, found at Glen Innes, clumps of *Sorghum plumosum* Beauvois, a native grass locally known as "wild sorghum," the leaves of which showed a striking fraying into tangled fibers much like that which *Sclerospora graminicola* (Sacc.) Schroet. produces in various Setarias. Since, however, the resting spores which he found among the injured leaf fibers differed somewhat in size and form from those typical of that common species of Sclerospora and since he knew the writer's interest in this genus, Dr. Noble very kindly sent the specimens to the writer for further study.

The fungus, indeed, proves to be a new species quite distinct from the related *S. graminicola* in the structure and color of the spores as well as in their consistently smaller size. Moreover, it occurs, apparently endemic, under natural conditions on a wild grass native to Australia, a species which has not been reported as host for any Sclerospora hitherto. For these reasons it is hoped that the following note may be of interest.

EFFECT ON THE HOST

In general appearance the infected plants were somewhat dried and shrivelled while the leaves, through disintegration of the tissue between their fibrovascular bundles, had shredded into tangled skeins of withered thread-like fibers (Fig. 1, A). Such symptoms are typical of advanced development of the oogonial resting-spore phase of a number of species of Sclerospora, and, as was natural, very few traces of the earlier lineate discolorations of the leaves still lingered. No evidences of a conidial or sporangial phase were seen. The mycelium, as was to be expected in an oogonial infection thus far matured, persisted as scanty, shrivelled fragments of contorted, irregular hyphae, here and there in the interstices

[1] For a grant from the Milton Fund of Harvard University which has made possible this and other comparative studies of the Sclerosporas, the writer wishes to express his gratitude.

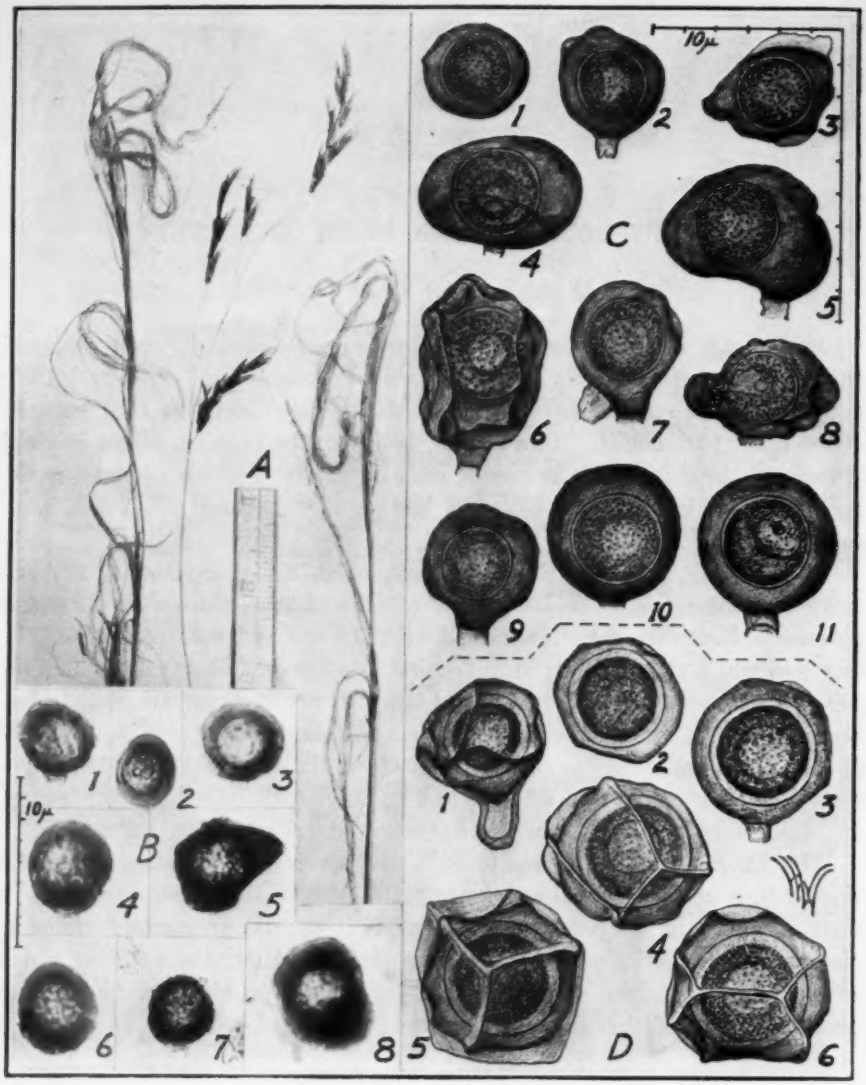

FIG. 1. A. Specimens of *Sorghum plumosum*, infected by **Sclerospora noblei** n. sp. from material collected at Glen Innes, New South Wales, in February, 1928, by Dr. R. J. Noble, showing the characteristic fraying of the infected leaves into tangled snarls of fibrovascular bundles with few fragments of disintegrated interfascicular tissue. Portion of healthy inflorescence shown in the center for contrast. Photograph, scale in inches, × ½.

B. Resting spores of **S. noblei**, showing their characteristic shape and structure and the relatively small size and thin wall of the oospore within. Photomicrographs, scale in microns, present magnification about 250 ×.

C. Resting spores of **S. noblei**; figures 1 to 4, 7, and 9 to 11 being most typically representative in their rounded shape, relatively smooth surface and thick dark oogonial wall, and in the relatively small size and thin wall of the oospore; figures 5, 6 and 8, showing the less regular forms occasionally seen. Camera lucida drawings, scale in microns, magnification about 375 ×.

D. Resting spores of *S. graminicola* var. *Andropogonis Sorghi* Kulk. from *Sorghum vulgare* from India. Figures 1 to 3 from Kirkee, India, collected by S. N. Mitra, March 10, 1905, kindly furnished by E. J. Butler, comparable to those of **S. noblei** in size, shape and configuration but distinguished by their larger and thicker walled oospores. Figures 4 to 6, from Bombay, India, collected by Dr. B. N. Uppal, December 10, 1927, and sent by him, more obviously distinct from **S. noblei** and more nearly approaching typical *S. graminicola* of Setaria in the polyhedral shape and ridged prominences of the oogonium. Drawings and magnification as in C.

between the disorganized leaf cells. In a few clumps only did Dr. Noble find cases of foliar proliferation on less heavily infected plants.

CHARACTERISTICS OF THE FUNGUS

The resting spores, which were produced in great numbers in the diseased plants, were visible, even through a hand lens, as minute, glistening, resinous-looking specks clinging among the fragments of disorganized tissue along the vascular bundles. In this, as in other species of Sclerospora, the resting spores are heavy-walled bodies comprising the spore proper, a spherical, hyaline, thick-walled oospore, surrounded by an outer coat, the closely adherent oogonial wall, usually much thickened, dark in color and decidedly modified in composition. In its shape, the resting spore, or more properly the oogonium, is usually approximately ovoid, ellipsoid, pyriform, or subspherical (Fig. 1, B 1–4, 6–8, C 1, 2, 4, 7, 9–11); occasionally somewhat angular with a few bluntly-rounded projections protruding unsymmetrically (Fig. 1, B 5, C 3); rarely very irregular, perhaps almost pyramidal, or gibbously bulging with large bulbous outgrowths (Fig. 1, C 5, 8).

The oogonial wall is typically very thick and dark. Its outer surface may be quite smooth, or it may be somewhat roughened and scabrous with irregular scabby patches. Occasionally it rises to rounded bulging protrusions (Fig. 1, C 2, 8), or even to narrow wing-like outgrowths (Fig. 1, C 3), and rarely to inconspicuous ridges, indistinctly anastomosing, but even on oogonia of very irregular shape the surface does not show the flattened, somewhat polygonal faces bounded by definite intersecting ridges that are noticeable in *Sclerospora graminicola* (*cf.* Fig. 1, D 4–6). The surface sculpturing on resting spores of Sclerospora as a whole appears to result in part from the fact that as the spore increases in size its developing wall conforms to the spaces between the surrounding host cells as they are forced apart, and also from the fact that fragments of the walls of cells thus killed become modified, darkened and confluent with the spore surface. The superficial configuration, therefore, may vary somewhat according to the tissue structure of the host leaf in which the spores develop. Hence it is possible that if this Sclerospora from *Sorghum plumosum* should infect other hosts, differences in the surface markings of the spore wall might develop in conformity to the different cellular structure of the surrounding tissue.

In color the oogonial wall varies considerably, ranging from the Mars Yellow (15 i), of Ridgways "Color Standards" to a rich brown (Brussels Brown 15 m), with a shade like that of dark amber near Sudan Brown (15 k) perhaps the most common.

The wall is typically very closely adherent to that of the single oospore within, seldom showing even small crevices between them, and never arch-

ing out into angular prominences which leave relatively large spaces around the oospore within, as is characteristic in the resting spores of some of the larger species of Sclerospora. In this species the surface irregularities, the angular, ridged, or rounded prominences, involve actual thickenings of the wall and do not result from outfolding or outbuckling of a wall of more uniform thickness. Consequently the enclosed oospore, although usually nearly central, is in some cases eccentric in position (Fig. 1, C 4–6, 10). Also it may occupy only a relatively small part of the whole body (Fig. 1, C 4, 5, 6), its diameter being perhaps $\frac{1}{2}$ or $\frac{1}{3}$ or rarely even as little as only $\frac{1}{4}$ of the greatest outside dimension of the resting spore as a whole.

Adhering to the oogonium there is frequently a portion of what had been the oogonial stalk (Fig. 1, B 2, 4, 7, C 2, 4–11), a small hyphal fragment, usually hyaline, pallid yellow, or golden, rarely as dark as the thick oogonial wall. This fragment is much more frequently present than in such species as *Sclerospora graminicola* and shows the oogonial nature of the resting spore rather clearly. This frequent occurrence leads one to believe that the oogonia had, for the most part, developed terminally on branches of the mycelium within the host tissue. Very rarely there may be seen, adhering to the oogonium, a fragment which might be interpreted as the remnant of an antheridium (Fig. 1, C 7).

The outside dimensions of the resting spores, as would be expected in bodies varying so markedly in shape, show considerable range, the diameter when approximately spherical, or the greatest dimension when irregular, varying from 28 to 44 μ (*cf.* Fig. 1, B 1–8, C 1–11). The thickness of the oogonial wall, most commonly ranging from 5 to 10 μ, at times may be as little as 3 μ, but very frequently in thickened spots is as much as 20 μ.

The oospores are almost invariably spherical in shape. Their size also is very uniform, the relatively narrow range, from 23 to 28.9 μ in diameter, including 508 of the 600 spores measured, with the size mode falling in the class (containing 230 spores) between 25 to 26.9 μ. The wall is quite smooth, of tough, homogeneous material, hyaline or with a faint tinge of golden or very pale amber color, varying somewhat in thickness but most frequently 1 to 1.5 microns, distinctly thinner than that of most other species.

The content of the oospore is hyaline or of the pallid grayish color of protoplasm, with a finely granular matrix in which occur denser granulation and clumps of granules, frequently showing at or near the center an irregular vacuolate or clear area in which, or perhaps slightly to one side, occurs a refractive, oily, slightly gold-tinged substance, either as several small globules (Fig. 1, B 1, 2), or as one large mass (Fig. 1, B 4, C 4, 6). These structural features were determined, not only from oospores freed

TABLE 1.—*Measurements of the diameters of 600 oospores of Sclerospora noblei arranged in size classes to show frequencies*

Diameter	
Classes	Number of oospores in 600
μ	
19 to 20.9	4
21 to 22.9	27
23 to 24.9	114
25 to 26.9	230
27 to 28.9	164
29 to 30.9	56
31 to 32.9	13
33 to 34.9	2

from the enclosing oogonial wall by careful manipulation, but also from those still in place in material mounted in lacto-phenol or similar clearing mixtures. The measurements given in table 1 were made, in distilled water, of oospores still *in situ*, as by proper adjustment of light it was found, on comparison with free oospores, that measuring thus was satisfactorily accurate.

Germination of the oospores was not observed.

IDENTITY OF THE FUNGUS

In connection with the identity of this fungus the only one of the known Selerosporas that need be considered is *S. graminicola*. This species, because its general effect on the host is similar, because its resting spores approach those of the Australian in size, and because it is the only member of the genus which, in its oogonial condition, has been reported on any sorghum, naturally invites comparison. For such comparison, material of *S. graminicola* on Setaria (Chaetochloa) is presumably most typical, as on this genus of grass the species was originally described and with very few exceptions has been reported since. From such typical material of *S. graminicola* the Australian species stands out without possibility of confusion, for the size, structure and color of the resting spore (*i.e.*, oogonial) wall, and the dimensions of the oospore within, as given in detail above, distinguish it sharply from *S. graminicola* in which the resting spores are larger in outside dimensions, usually have flattened polygonal faces bounded by intersecting ridges, very rarely show any traces of an oogonial stalk, have an oogonial wall that is thinner, of paler color, more transparent, less variable in thickness, arching out here and there to leave distinct spaces around the oospore within; while the oospore itself is markedly larger, most

frequently 33 to 34.9 μ in diameter, and the wall much thicker, most frequently 2 to 4 μ, as opposed to the 25–26.9 μ diameter and 1 to 1.5 μ wall thickness of the Australian.

It is necessary, also, to compare the Australian species with material which in a few cases has been described as *S. graminicola* on cultivated sorghum (*Sorghum vulgare* Pers., *Holcus sorghum* L., *Andropogon sorghum* Brot.) in Africa (3), and in India (2, 4). From India, specimens kindly furnished by Butler, by Kulkarni, and by Uppal have been examined and found to show some differences from the typical *S. graminicola* chiefly in size of the oospores, which in some lots show the most common diameter of 37 to 38.9 μ even when the general characters of shape, size and surface of the oogonia (*cf.* Fig. 1, D 4–6) agree with typical material. That there are differences in the oogonial phase on this host is in agreement with the fact that Kulkarni (4) found in the conidial phase the very distinctive character that the conidia germinated always by germ tubes, not zoospores, and on it he established the variety *Andropogonis sorghi.* In a recent letter also Dr. B. N. Uppal reports that in his cross inoculations he finds, as did Kulkarni, that spores from sorghum will easily infect sorghum but not other hosts. All this seems still further to bear out the writer's suggestion (6, p. 781) that this variety is specifically distinct from *S. graminicola* and stimulates interest, in the case of the Australian species, in determining the characteristics of its conidial phase, if, indeed, one does develop, and in finding what may result from extensive cross inoculations to sorghum and related crops.

The specimens on sorghum from India do show some resting spores which in general shape, surface contour, and size, approximate those of the Australian species (*cf.* Fig. 1, D 1–3). Even these, however, are distinguished by the larger size of the oospores (167 out of 200 falling between 33 to 40.9 μ in diameter) and the greater thickness of their wall, which is most frequently 1.5 to 4 μ.

When all these points are considered it seems clear that this Australian species is distinct, not only from typical *S. graminicola,* but also from its variety on cultivated sorghum and must be recognized as a separate species.

Its diagnosis, therefore, is given as follows:

Sclerospora noblei. Resting spores showing rather obviously that they comprise a modified oogonium with oospore within. Oogonium usually ovoid, ellipsoid, pyriform or subspherical in shape, occasionally with bluntly rounded projections rendering it gibbous and unsymmetrical, ranging in diameter from 28 to 44 μ. Oogonial wall closely adherent to the oospore within, the exterior protrusions not representing outbulgings, but rather involving actual increases in thickness of the wall, which most commonly is 5 to 10 μ, at times only 3 μ, often as much as 20 μ. Wall dark, often

scarcely transparent, color ranging from somewhat golden (Mars Yellow Ridgway) to rich brown (Brussels Brown Ridg.), most commonly dark resinous amber (Sudan Brown Ridg.). Fragment of oogonial stalk frequently adherent. Oospores regularly spherical, most frequently from 23 to 28.9 μ in diameter, the mode between 25 to 26.9 μ, extremes ranging from 20 to 34 μ; wall hyaline to pale golden, 1 to 1.5 μ thick; content finely granular with aggregations of denser material and with masses of oily reserve substance, central to eccentric in position.

Germination not yet observed.

Occurring on *Sorghum plumosum* Beauv. at Glen Innes, Guyra and other points lying west of the New England range in New South Wales, in February, 1928, collected by R. J. Noble.

Specimens deposited in the Farlow Herbarium, Harvard University.

DISCUSSION

The occurrence of this new Sclerospora, as found by Dr. Noble on *Sorghum plumosum* in New South Wales, involves certain points of interest.

In the first place, this host adds another species to the long list of grasses that are attacked by the ten or more Sclerosporas in various parts of the world. Hitherto the cultivated sorghum, *Sorghum vulgare* Pers. has been the only member of this gramineous genus reported as harboring a Sclerospora. On this crop there has been reported, both from India and Africa, a species which, in its oogonial phase, resembles *Scl. graminicola*, but which, in its conidial stage, shows distinct differences that, as have been noted, distinguish it sharply from that widespread form.

Moreover, the Sclerospora itself is a species as yet undescribed, readily recognizable by the small size of its oospores (smaller than that of any other species) and their thin wall, and also by the rounded, rather than flattened, exterior of the oogonium, whose rounded surface prominences result from actual increased thickness of the dark wall, closely in contact with the oospore within, and not from out-bulgings.

In the second place, the host, *Sorghum plumosum* Beauv., the *Holcus plumosus* of R. Brown, the *Andropogon australis* subsp. *plumosus* of Sprengel, is endemic to Australia. It occurs, according to Turner (5), Bentham and Mueller (1), and others, in all the eastern colonies, and also in North Australia; very plentiful in the coastal regions along the Hasting's, McLeay, and Clarence rivers from Port Jackson to the Blue Mountains of New South Wales, and also in the New England district where, when in flower, it is reported as a noticeable feature of the landscape in the pastures.

The obligate parasitism of this endemic grass by a distinct species of Sclerospora, as yet known only on this host, may perhaps indicate that the parasite also is endemic to the region. As our knowledge of the geographic distribution and the host range of the Sclerosporas increases, it will be of interest to note whether this is verified.

In the third place, the occurrence of this Sclerospora on this grass in Australia may prove to be of economic importance. *Sorghum plumosum* is described as a valuable wild forage grass, its herbage, less coarse and heavy in the cooler parts of Australia, affording widespread fodder for grazing sheep, and its abundant seed heads furnishing a grain on which horses are said to thrive. As now known the Sclerospora is not devastatingly destructive to the wild sorghum, and it is probable that this balance is the result of long association and will not suddenly be upset. It seems probable, however, that if future conditions of stock-raising should lead to greater and greater dependence on this grass as fodder and several successive seasons with such conditions as excessive rainfall should favor unusually severe development of the fungus, it might prove of importance.

It is more probable, however, that the fungus may prove of economic importance by passing from this to other more valuable cultivated grasses. As most of the species of Sclerospora are not narrowly limited but have a considerable range through species and genera of hosts, it is to be expected that this may occur in the future, especially if changes in agricultural practice bring many gramineous crops within range of infection. The wild sorghum is perennial and the new growth in colder regions of its range starts in September to October (the beginning of "summer"), while in warmer localities it is continuous and the Sclerospora developing with it affords a constant reservoir of infection. The other species of Sorghum in Australia, *Sorghum fulvum* Beauv., occurring also in tropical Asia, and the cultivated sorghum, *Sorghum vulgare* Pers., world-wide and with many varieties, may in time contract the disease, the latter, in some of its many varieties, having possibilities as a valuable crop there, as in other parts of the world. From the behavior of other Sclerosporas it is possible this species may prove destructive to some other gramineous crop either in the Andropogoneae or the Maydeae or perhaps even some more distantly related tribe.

SUMMARY

This paper discusses a Sclerospora found by R. J. Noble in New South Wales, Australia, on *Sorghum plumosum* Beauvois, a native grass locally called "wild sorghum."

In its resting-spore stage, the only reproductive phase yet found, the oospores are of smaller size, mostly between 23 and 28.9 μ in diameter, with a thinner wall, mostly from 1 to 1.5 μ in thickness, than any known Sclerospora, while the thickness, color, and contour of the oogonial wall also mark this as a species as yet unrecorded. It is, therefore, described as *S. noblei* n. sp. and its distinguishing features of size and structure are considered in detail and compared with related forms.

As the host on which the fungus occurs is endemic to Australia the possibility is advanced that the fungus, also, may be endemic.

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LITERATURE CITED

1. G. BENTHAM and F. MUELLER. Flora Australiensis. Vol. 7. Gramineae. 1878.
2. BUTLER, E. J. Some Diseases of Cereals caused by Sclerospora graminicola. Mem. Dept. Agr. India Bot. Ser., V. 2, No. 1, 24 p., 5 pl. 1907.
3. BUNTING, R. H., and H. A. DADE. Gold coast plant diseases. Waterlow & Sons, London. 124 pp. illus. (No date.)
4. KULKARNI, G. S. Observations on the Downy Mildew (*Sclerospora graminicola* (Sacc. Schroet.) of Bajri and Jowar. Mem. Dept. Agr. India Bot. Ser. V, 5, p. 268–273, pl 6–7. 1913.
5. TURNER, F. Australian grasses. Gov't. Printer, Sydney, N. S. Wales, V. 1, illus. 1895.
6. WESTON, W. H. Nocturnal production of conidia by Sclerospora graminicola. Journ. Agr. Research, V. 27, No. 10, p. 771–784, pl. 1–2. 1924.

CERTAIN EARLY DEVELOPMENTAL PHASES COMMON TO MANY FUNGI[1]

G. HAMILTON MARTIN[2]

For some time there have been observed organisms which were associated with diseased conditions in plants, such as wilt, scorch, yellowing, leaf-spotting, anthracnose, die-back, scab, and melanose. These organisms either have remained undetermined or have been placed in various genera that are much alike in their spore forms. The following examples are illustrative. On rose leaves there is often observed a crinkling and yellowing interspersed with areas of normal green, or, again, a red spotting of leaves, stems, petals, thorns, and hips. On the lily, iris, lilac, pear, privet, poplar, and Vinca a fire-blight effect is found. On the iris and lily a purple coloration followed by chlorosis resulting in spots distinctly grayish or whitish in dry weather and reddish brown under humid conditions has been observed. On lilac, Hydrangea, and Viburnum a blighting of shoots occurs characterized by a distinct burning or scorching of leaf and twig, after which the tissues turn brown or black and the diseased parts become brittle and persistently adhere to the plant. A study of these diseases demonstrates that the causal organisms have certain common developmental phases. Pseudosaccharomyces and Pseudofumago were used by Briosi and Farneti (5) as names of form genera. The writer regards these as mere budding and fumagoid phases of perfect stages of various fungi. It appears that the yeast-like or budding phase and the fumagoid phase play an important part in the life history of various fungi. The former phase presents less variation than the latter, as is shown later in this paper.

That the special type of growth produced is largely influenced by conditions of temperature and humidity as well as kind of media used is borne out by numerous cultural studies. Field observations also indicate that in nature these phenomena may be correlated with seasonal, weather, and soil conditions.

No doubt the budding phase which in culture presents a cloudy, slimy or watery appearance has been encountered by other workers and thought to be of bacterial origin because of its resemblance to bacterial growth. Although these fungi in their final phases are often associated with such symptoms as previously stated, there is yet no experimental evidence that they are pathogenic except when nutritional or climatic conditions affect

[1] Subsequent articles will give the details supporting the hypotheses in this paper.

[2] The writer is under obligation to Mr. J. F. Brewer for the photographic work illustrating this article.

the host so adversely as to make infection possible. Tissue decomposition is not always present in areas discolored or otherwise affected by the budding or fumagoid phases.

The Pseudosaccharomyces phase is characterized by conidia which may be borne in a whorl or produced at the apex of a terminal cell or on a protuberance which arises from any of the cells along the course of the fumagoid mycelium. The conidia are spherical to oblong-elliptical, apiculate or entire, hyaline, at times changing to brown, greenish-black, or black or they may continue to form bud cells. In the Pseudofumago phase the filaments may be hyaline, brown, greenish-black or black. They are septate and may produce papillae on which the budding spores are formed by sprout cells. At times the mycelium may become moniliform by means of segmentation; these segments may then become larger, the membrane thicker and darker. These cells are comparable to chlamydospores. Great variation may be observed in the formation of these spores. One or more cells may separate, develop thick walls. At times they divide transversely and may be easily mistaken for the spores described for the genus Coniothecium. These spores are capable of immediate germination or may function as resting spores. Various growth manifestations are exhibited by the fumagoid filaments during the transitional developmental periods which show an unusual polymorphism. The spores of Pseudofumago may either give new fumagoid chains, Pseudosaccharomyces, Cladosporium, or Hormodendron. The fumagoid phase can be obtained directly from the budding spores or from spores of Cladosporium or Hormodendron. Considerable similarity has been noticed between the development of spores in corymbs or clusters in Pseudosaccharomyces, Cladosporium, and Hormodendron. These phases are not only found in stems, leaves, flowers, seeds, or fruits but also in bulbs, rhizomes, and roots.

Certain form genera have been described which have phases that are indistinguishable from the budding or fumagoid phases. The following are some of those observed during the present investigation:

Dematium pullulans de Bary.
Fumago vagans Pers.
Kabatiella Vassil.
Polyspora Lafferty.
Protocoronospora Atk. & Edgert.
Exobasidiopsis Karak.
Pachybasidiella Bub. & Syd.
Microstroma Niessl.
Sphaceloma de Bary.
Aureobasidium Viala & Boyer.

During the course of the studies here recorded, types of Pseudosaccharomyces and Pseudofumago phases have been isolated from 50 different hosts as given in the following list:

Acer dasycarpum pyramidula
Aquilegia sp.
Begonia sp.
Buxus sempervirens
Carthamus tinctorius
Catalpa sp.
Chrysanthemum sp.
Colchicum autumnale
Convallaria majalis
Cornus sp.
Dahlia sp.
Dianthus barbatus
Funkia sp.
Fuchsia sp.
Gladiolus sp.
Gleditsia triacanthos
Hemerocallis fulva
Hicoria pecan
Hippeastrum equestre
Holcus sorghum
Holodiscus discolor
Hydrangea sp.
Iris spp.
Juglans spp.
Juniperus procumbens
Lathyrus odoratus
Lavendula sp.
Leucothoë sp.
Ligustrum ovalifolium
Lilium spp.
Maclura pomifera
Myosotis sp.
Narcissus sp.
Paeonia officinalis
Papaver orientale
Pelargonium sp.
Phaseolus lunatus macrocarpus
Philadelphus sp.
Pinus sp.
Polygonatum sp.
Populus sp.
Pyrus communis
Rhododendron spp.
Rosa spp.
Salvia sp.
Symphoricarpos sp.
Syringa vulgaris
Vicia villosa
Vinca minor
Wisteria sp.

An examination of literature shows that certain investigators have observed the budding and fumagoid phases in connection with the study of some particular organism but they appear not to have emphasized the fact that these phases are common to a large number of widely separated genera. Bennett (2) states that *Anthostomella pullulans* is the perfect stage of *Dematium pullulans*. Schwarz (15) describes and illustrates a yeast-like organism, which she designates as the A and B stages of *Graphium ulmi*. Klebahn (10) does the same for *Guignardia pullulans* on the iris and places the conidial phase in the genus Sporotrichum Link. Martin and Charles (11) found a like phase in connection with the life history of *Erostrotheca multiformis*. Fusicladium has been found by Aderhold (1) and other workers to be an imperfect form of Venturia; Brefeld (3) illustrates a budding phase for a number of Ascomycetes. His figures of the budding and fumagoid phases for *Sphaerulina intermixta* are excellent in their delineation of the polymorphism of sprout-cell formation. He calls this phase *Dematium pullulans*. It is interesting to note that Gäumann and Dodge (6) refer to this early phase of *S. intermixta* as follows: "This type of germination has not been reported elsewhere in the group and probably was based on impure cultures." This same idea has been held by a number of workers. Janczewski (7) found *Dematium pullulans*, Cladosporium and Hormodendron phases in connection with the life history of *Mycosphaerella*

tulasnei. Brefeld (4), Sadebeck (14), Pierce (13), Klebahn (9), Mix (12), and Jankowska (8) have obtained the budding or yeast-like cells in connection with cultural studies of the Exoascaceae.

An extensive cultural study by the writer of *Leptosphaeria coniothyrium* on the rose has shown that the early phases of the organism are Pseudosaccharomyces and Pseudofumago, from which pycnidial phases of Phoma, Phyllosticta, and Coniothyrium were derived. The early phases were observed to be present in the host tissue long before the canker was in evidence. The first external manifestations are wilting of leaf, shoot, and bud and red spotting on the twig, spine, leaf, petal or outer bud coat, and on the hip. The presence of the fungus is indicated by a dwarfing, a yellowing, and a distortion or wrinkling along the veins and midrib of the leaflets.

A red spotting or generalized stippling of stems, leaves, and flowers of Paeonia has been frequently reported. It is apparently what has been designated as anthracnose, a disease which Whetzel (16) conjectures to be due to a fungus producing definite though incomplete fruiting bodies. Others have supposed that it might be a physiological injury resulting from unbalanced nutrition. This type of injury was very prevalent during the spring of 1929. Many specimens were received by the writer or collected. The budding and fumagoid phases were consistently found. Similar fruiting structures were often found in abortive buds which showed symptoms like Botrytis bud blight but failed to yield Botrytis. From the stem lesions, leaf spots, and bud lesions, *Cladosporium paeoniae* developed directly on the plant and also when the budding organism was isolated in culture.

In April, 1927, species of lilies growing in Washington, D. C., were found by Vera K. Charles to be affected with a fungus that corresponded to the description of *Kabatiella microstricta* Bub. The plants presented a scorched appearance. Since then many specimens have been collected and received which, on examination, yielded an organism that corresponds morphologically and culturally with the budding and fumagoid phases dealt with in this paper. The symptoms are varied, such as grayish-white, diffused areas, scorch, wilt, rosette, abortive buds, leaf yellowing and mottling, a general blighting of leaf and bud, and a rusty appearance on bud scales and leaf. The latter condition on leaves has been called "frost injury." The organism has been isolated from all parts of the plant, including the vascular system of the bulb scales. The infection in the bulb scale is of great importance since this can be a means of spreading the disease through propagation by scales. That the organism can also be carried by the mite, *Rhizoglyphus hyacinthi,* which inhabits the bulb, has been demonstrated by taking mites from infected bulbs and placing them in tube cultures and also by examination of the mite.

During the spring of 1929, Iris in several localities was severely affected by an organism similar to that found on the lilies. It causes a general blight, a browning of the leaf tips, a scorch or wilting of the plant. A fungus of this type has been found in and isolated from the leaf, rhizome, and roots of the plant.

Pure cultures made from single spores or segments of the Pseudosaccharomycetous and Pseudofumagoid phases from various hosts have developed fruiting boidies of the following form genera. Following the name of the fungus the hosts from which such an organism was isolated are listed.

Ascochyta—Vicia villosa.

Cladosporium-Hormodendron—Aquilegia, Begonia, Catalpa, Chrysanthemum, Convallaria, Cornus, *Dianthus barbatus, Gleditsia triacanthos, Hicoria pecan, Holcus sorghum, Iris germanica, Juglans cinerea, J. nigra,* Lavendula, *Ligustrum ovalifolium, Lilium* spp., *Papaver orientale,* Philadelphus, Populus, *Pyrus communis,* Rhododendron, Symphoricarpos, *Syringa vulgaris, Vicia villosa,* Vinca, Wisteria.

Colletotrichum—Hydrangea, Paeonia, Symphoricarpos.

Coniothyrium—Gleditsia triacanthos, Paeonia, Rosa.

Fusicladium—Pyrus communis.

Gloeosporium—Hydrangea, Paeonia, Symphoricarpos.

Kabatiella microstricta—Convallaria, Iris, Lilium.

Kabatiella nigricans—Vicia villosa.

Kabatiella polyspora—Acer dasycarpum pyramidula.

Marssonina—Aquilegia.

Microstroma juglandis—Hicoria pecan, Juglans cinerea, J. nigra.

Phoma—Rosa, *Syringa vulgaris, Vinca minor.*

Phyllosticta—Aquilegia, *Dianthus barbatus,* Hydrangea, *Hicoria pecan, Holcus sorghum, Hippeastrum equestre, Iris germanica, Ligustrum ovalifolium,* Paeonia, Polygonatum, Rosa, *Vicia villosa,* Vinca, Wisteria.

Sclerotium—Lilium, Convallaria, Iris.

Glomerella cingulata (Ston.) Spauld. & Schrenk—Hydrangea, Paeonia, Symphoricarpos.

Pleosphaerulina sp.—*Hippeastrum equestre, Holcus sorghum.*

SUMMARY

Budding or yeast-like cells have been observed associated with diseased conditions such as wilt, scorch, yellowing, leaf spotting, anthracnose, dieback, scab, melanose, rosette, dwarfing and shoot blighting on fifty different hosts. A study of these diseases demonstrates that the causal organisms have common developmental phases which play an important part in the life history of various fungi. The terms Pseudosaccharomyces and Pseudofumago are used for the early phases. A description is given for each.

Mention is made of a number of instances in literature where the budding and fumagoid phases have been observed in connection with the study of some particular organism.

Species of Ascochyta, Cladosporium-Hormodendron, Colletotrichum, Coniothyrium, Fusicladium Gloeosporium, Kabatiella, Marssonina, Microstroma, Phoma, Phyllosticta, Sclerotium, *Glomerella cingulata*, and Pleosphaerulina have been developed from single spores or segments of Pseudosaccharomyces and Pseudofumago in culture.

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LITERATURE CITED

1. ADERHOLD, R. Die Perithecienform von *Fusicladium dendriticum*. Ber. Deutsch. Bot. Ges. 12: 338–342. 1894.
2. BENNETT, F. T. On *Dematium pullulans* and its ascigerous stage. The Annals of Applied Biology 15: 371–391. 1928.
3. BREFELD, OSCAR. Untersuchungen aus dem Gesammtgebiete der Mycologie. Heft 10. 1891.
4. ————. Die formen der Ascomyceten und ihre Culture in Nährlösungen Untersuchungen aus dem Gesammtgebiete der Mykologie 9: 119–149. Munster, 1891.
5. BRIOSI, GIOVANNI, and RODOLFO FARNETI. Intorno alla ruggine bianca dei limoni. Isti. Bot. della R. Univ. di Pavia, Ser. II, 10: 1–58. 1907.
6. GÄUMANN, E. A., and C. W. DODGE. Comparative Morphology of Fungi. 1st ed. N. Y. McGraw-Hill Book Co., 1928.
7. JANCZEWSKI, E. Polymorphism du *Cladosporium herbarum*. Bull. Acad. Sci. de Cracovie 30: 417. 1892.
8. JANKOWSKA, KRYSTYMA. Exoascaceae of Poland. Mem. Inst. National Polonais d'Econ. Rur. à Pulawy. 9: 182–215. 1928.
9. KLEBAHN, H. Infektionsversuche mit *Taphrina Iosquinetii*. Berichte der deutschen Bot. Ges. 41: 108–113. 1923.
10. ————. Ueber drei auf Iris gefundene Perithezien und die zugehörigen Konidienpilze. Ber. Deut. Bot. Gesell. 42: (60)–(71). 1925.
11. MARTIN, G. HAMILTON, and VERA K. CHARLES. Preliminary studies of the life history of *Erostrotheca multiformis*, the perfect stage of *Cladosporium album* Dowson. Phytopath. 18: 839–846. 1928.
12. MIX, A. J. Biological and cultural studies of *Exoascus deformans*. Phytopath. 14: 217–233. 1924.
13. PIERCE, N. B. Peach leaf curl; its nature and treatment. United States Department of Agriculture, Div. Veg. Phys. and Path., Bull. 20: 11–204. 1900.
14. SADEBECK, R. Die parasitischen Exoasceen, ein Monographie. Jahrbr. der Hamb. wissensch. Anst. 102: 5–10. 1893.
15. SCHWARZ, M. B. Das Zweigsterben der Ulmen, Iranerweiden und Pfirsichbäume, ein vergleichend-pathologische Studie, Utrecht. A. Oosthoek. pp. 7–32. 1922.
16. WHETZEL, H. H. Diseases of the peony. Trans. of the Mass. Hort. Soc. pt. 1. 1915.

EXPLANATION OF PLATES

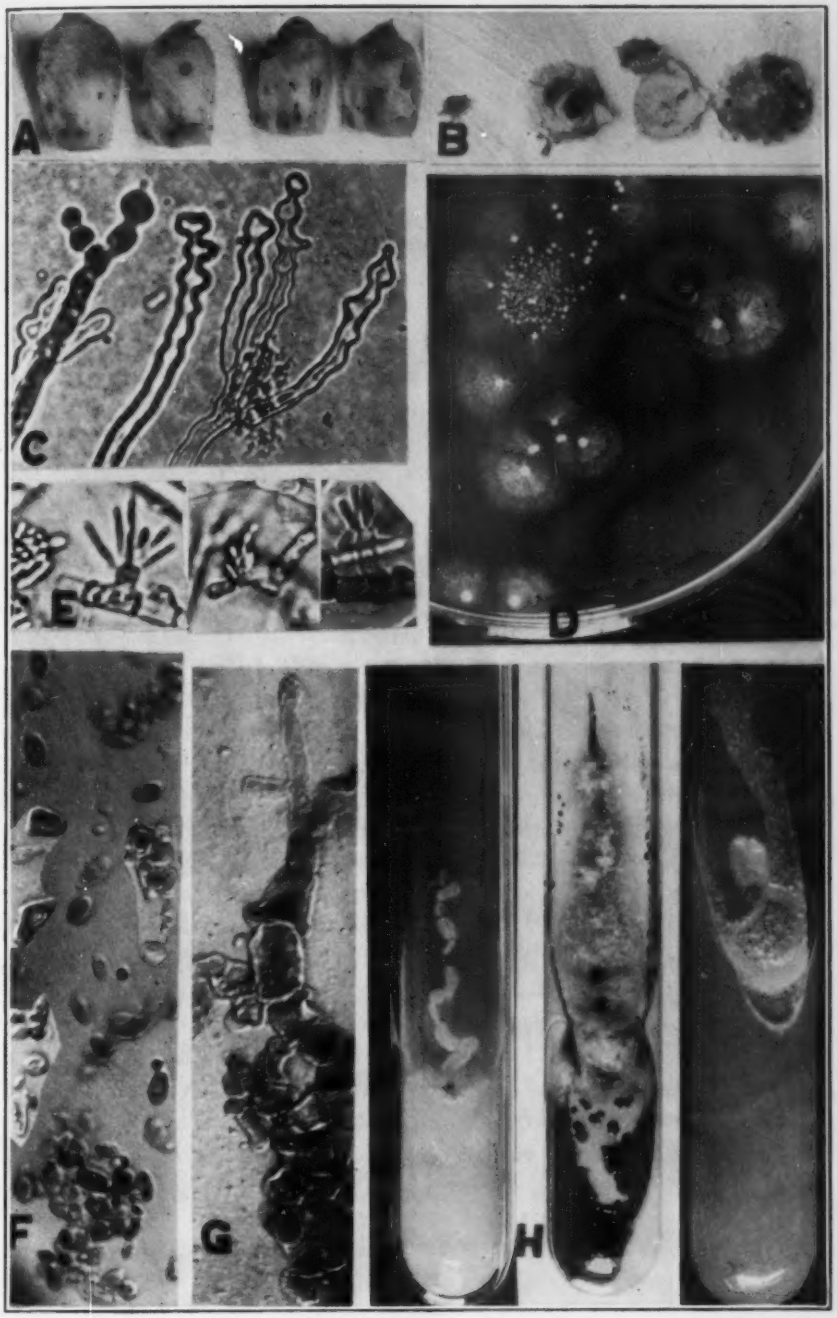
PLATE XXXVII

A. Blossom blight of Hydrangea.
B. Shoot blight of lilac.
C. Scorch of Iris.
D. Anthracnose and bud blight of peony.
E. Scorch of lily.
F. Spotting and young lesions caused by *Leptothyrium coniothyrium* on the rose.

PLATE XXXVIII

A. Natural infected bulb scales of lily by *Kabatiella microstricta*.
B. Cross-section of lily bulb showing vascular infection.
C. Photomicrograph of young, moniliform filaments of Pseudofumago from *Lilium* sp.
D. Petri-dish culture of colonies of budding spores from *Lilium* sp.
E. Whorl or cluster formation of budding spores on fumagoid filament from *Lathyrus odoratus*.
F. Pseudosaccharomycetous spores.
G. Pseudofumago mycelium from *Lathyrus odoratus*.
H. Cultures of budding phase resembling bacterial growth from *Lilium* sp.

A
B
C
D
E
F


A
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H

A TWIG CANKER OF APPLE CAUSED BY *NECTRIA CINNABARINA*

H. E. Thomas and A. B. Burrell

Early in the summer of 1927 the attention of one of the writers was drawn to an unusual blight of Rome apple twigs which, at a distance, somewhat resembled fire blight. It was found, however, that the death of the terminals was caused by small cankers originating in the cluster bases which had borne fruit the preceding season. Specimens taken in August, 1928, bore numerous sporodochia and conidia of a fungus indistinguishable from *Nectria cinnabarina* (Tode) Fr. (*Creonectria purpurea* (L.) Seaver). Thus far the canker has been seen by the writers in only a single orchard near Cardiff, in Central New York.

The cankers were fairly numerous and wide-spread on the Rome variety and were found in appreciable numbers on Northern Spy. None was found on McIntosh interplanted with the Romes or on Delicious or other varieties in neighboring blocks. *Nectria cinnabarina* was abundant in a planting of currants a few rods distant from the Rome trees. It is interesting that Durand records the occurrence of the same fungus on the pear in the same county in 1897.[1] *Nectria cinnabarina* has been found associated with the death of twigs and branches of many sorts of trees, including the apple in Oregon,[2] in New Zealand,[3] and apparently elsewhere, but experimental evidence of its causative relation in the case of the apple has not been found. Indeed, most of the infection experiments with this fungus on other plants have been attended either by failure or indifferent success. R. J. Haskell reports (letter of September 1, 1928) two collections of the conidial stage of this fungus on apple in the mycological collections of the Bureau of Plant Industry, one from Maine on a fruit spur and another from Washington, taken from a larger branch.

The disease is as yet of no great economic importance in the orchard under observation, although a maximum of several hundred dead fruit spurs may be found on a single tree.

The superficial resemblance of the symptoms of this disease to those of fire blight on twigs has been mentioned. The foliage and bark, however, do not assume the dark aspect associated with fire blight but rather a light

[1] Durand, E. J. A disease of currant canes. N. Y. (Cornell) Agr. Exp. Sta. Bul. 125. 1897.

[2] Zeller, S. M. Cankers of apple and pear in Oregon and their control. Oreg. Agr. Exp. Sta. Circ. 73. 1926.

[3] Cunningham, G. H. Coral-spot, Nectria cinnabarina (Tode) Fries. New Zealand Jour. Agr. 25: 354–359. 1922.

brown color. The bark and wood are killed from the tip of the cluster base downward to a distance of one to four inches. Branches arising from the cluster base are girdled and killed. Early in the season there are no conspicuous signs of the fungus but, later, the bright pink stromatic masses or sporodochia are borne in profusion on the dead bark, particularly that of the cluster base (Fig. 1).

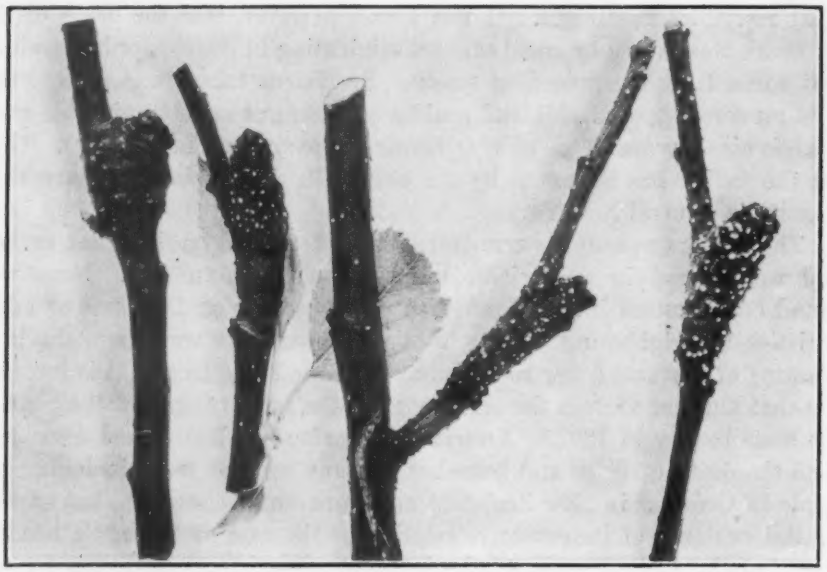

FIG. 1. *Nectria cinnabarina* on Rome apple fruit spurs. Collected in August.

In addition to the sporodochia already referred to, perithecia with viable ascospores were found on material collected on March 1, 1929. These agree in all essential details with the written descriptions of *N. cinnabarina*.

It was soon noted, however, that cultures from the cankers on Rome twigs differed in certain respects from those obtained from currant bushes in a garden at Ithaca. This led to a more extended comparison of some of the strains[4] from apple and currant obtained from ascospores, and conidia. Representative strains were grown on potato, potato-dextrose, oat, beef-peptone, and Czapek's[5] agars. Most of these cultures were made from two strains of the fungus, one from apple and one from currant. Good growth was obtained on all these media and on steamed apple twigs. Differences were observed between strains in growth rate, type of colony, and the num-

[4] The term strain is used to designate the line originating from a separate isolation and does not imply that differences exist between the lines so designated.

[5] Reed, H. S. A manual of bacteriology. Boston, 1914.

ber of sporodochia produced. In some instances the differences were striking but sufficient work has not been done to determine how nearly constant these differences may be. However, 30 strains from ascospore-dilution cultures all from the same source were indistinguishable on potato-dextrose agar with the exception that one strain produced sporodochia somewhat more readily than the others of this group. Twelve of these strains were matched in Petri-dish cultures, two strains to each culture. A slight antagonism was shown between colonies which was similar throughout these and other cultures. No other effect of matching was noted at the end of eight weeks.

The temperature relations of a strain from apple were studied on potato and Czapek's agars at 3, 9, 15, 21, 27–29, and 33 degrees Centigrade. Growth was slight at 3° and best at 21°. Moderate growth occurred at 27–29° and no growth at 33° C.

INFECTION EXPERIMENTS

Inoculations were made in the greenhouse on young apple trees of the varieties McIntosh and Wealthy and on grafted fruit spurs of the Rome, Northern Spy, and Winter Banana varieties. The inoculum was taken from agar cultures (originally from conidia) in the first trial and from cultures (ascospore from apple) on steamed wheat kernels in the second and third trials. The inoculations were made on wounds produced by heading back the terminals or by slitting the bark on the stem. In the case of the fruit spurs, the cluster base was split at the tip for a distance of one-fourth to one-half inch, making a rather severe wound. Following inoculation, the trees were maintained in a moist atmosphere for 5 to 7 days.

In the first experiment, 6 wounds on McIntosh and Wealthy trees of low vigor were inoculated with each of two strains of the fungus, one from apple and one from currant. No infection resulted.

Again, 4 Wealthy and 8 McIntosh trees growing in a greenhouse bed were inoculated when the first leaves were one-half inch to one inch long. Two inoculations were made on each plant. Growth in these plants, after 52 days, varied from a few clusters of leaves to the production of shoots 12 to 16 inches long. Of the 4 inoculated Wealthy trees, one tree died apparently due in part to causes other than the inoculation. Two of 8 uninoculated Wealthy trees died before the trees became rooted in the soil. In the three remaining inoculated Wealthies the fungus had advanced into the living tissues from two wounds but at most only one-half inch from the wound. The 8 inoculated McIntosh trees showed much more marked evidence of pathologic reaction. Five of them died outright and bore numerous sporodochia of the fungus. One plant produced a shoot 7 inches long

before it succumbed. The sixth inoculated plant bore a canker one-and-one-half inches long, while the two remaining plants showed only slight killing of the bark around the wounds. One of 8 uninoculated McIntosh trees died.

Inoculations on the fruit spurs were made within a few days of the time of grafting and are somewhat inconclusive in view of the rather severe wounding and the fact that 50 per cent of the uninoculated grafts failed to develop. However, it is of interest that on the Rome spurs the progress of the fungus down the stems was much more rapid than on Northern Spy or Winter Banana. Fifteen of twenty-four inoculated Rome spurs were entirely dead in 33 days and two more were nearly so. Only one of three inoculated Winter Banana spurs was dead and none of four Spy spurs was entirely so. There was evidence of killing beyond that attributed to the wounds on all except four of the 31 inoculated spurs.

Natural infection in the field apparently takes place in late autumn or early spring. The infection court is quite obviously at or near the point of detachment of the fruit from the cluster base. Ascospores were mature in 1929 in considerable numbers by March 1. On April 7, many cankers were found dead from the tip of the cluster base to a distance of a few millimeters to two or more inches. Observations indicate that there are few if any new infections developed during the summer, although conidia are produced in great profusion from midsummer on. The cankers of one season usually do not persist into the next.

The disease seems to be most abundant on trees of moderate vigor and less common on trees of very low or very high vigor.

SUMMARY

1. *Nectria cinnabarina* is consistently associated with a canker on apple twigs in one orchard in central New York.

2. Natural infection takes place at or near the point of detachment of the fruit from the cluster base.

3. From inoculated wounds the fungus is able to invade the tissues of several varieties of apples in degrees varying with the variety and with the growth condition of the plant.

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STEM-RUST-RESISTANT SEGREGATES FROM WHEAT CROSSES BETWEEN TWO SUSCEPTIBLE PARENTS[1]

GEORGE STEWART[2]

In addition to valuable economic forms, the breeding program to secure wheat strains resistant to stem rust is constantly yielding interesting scientific data in regard both to the rust organism and to the host plant. Some resistant segregates have been obtained at the Utah Agricultural Experiment Station from crosses between parents, one of which is fully susceptible and the other only mildly resistant. A recombination which gave semiresistant segregates from two susceptible parents has been reported by Hayes, Aamodt, and Stevenson.[3] From a cross between Federation, which is fully susceptible (100S), and Sevier No. 59, a pure line that is weakly semiresistant (75SR), the writer obtained and reported a fully-resistant segregate (R type of resistance).[4] Out of 18 segregates tested, 13 were fully susceptible (70–90S), 4 were semiresistant (50–65SR), and one was fully resistant (25R). Several other segregates had previously been obtained[5] when Sevier was one of the parents, but the reaction of the parental pure line of Sevier was not known.

A second fully-resistant segregate (R) was obtained in 1928, in which one parent, Federation, was completely susceptible (60S) and the other, Sevier No. 59, was of the semiresistant type. The breeding was done in 1924, 1925, and 1926 at Logan, Utah, where homozygous F_4 lines were secured in 1927. The rust tests were made in the rust nursery at St. Paul, Minnesota, in 1928.[6] In all, 26 strains were tested. Of these, 12 produced rust reactions of the purely susceptible type; 11 gave reactions of the semiresistant type or segregated for the susceptible and semiresistant types; 2 strains segregated for the semiresistant and resistant types of reaction; and

[1] Contribution from Department of Agronomy, Utah Agricultural Experiment Station.

[2] Agronomist in charge plant breeding. Publication authorized by Director of the Utah Agricultural Experiment Station, May 21, 1929.

[3] Hayes, H. K., O. S. Aamodt, and F. J. Stevenson. Correlation between yielding ability, reaction to certain diseases, and other characters in spring and winter wheats in rod-row trials. Jour. Amer. Soc. Agron. 19: 896–910. 1927.

[4] Stewart, George. Origin of a segregate resistant to blackstem rust in a cross between two susceptible parents. Amer. Nat. 62: 188–192. 1928.

[5] Stewart, George. Correlated inheritance in wheat. Jour. Agr. Res. 33: 1163–1192. 1926.

[6] The writer gratefully acknowledges his indebtedness for the rust readings to the following: Dr. H. K. Hayes, Head, Division of Agronomy, Minnesota Experiment Station; Dr. E. C. Stakman, Head, Section of Plant Pathology, Minnesota Experiment Station; and K. S. Quisenberry, Associate Agronomist, U. S. Department of Agriculture, quartered at Minnesota Station cooperating on rust studies.

one strain was fully resistant (15R). The Federation parent was again completely susceptible (60S) and the Sevier No. 59 parent was semiresistant (50SR). The data are presented in table 1.

TABLE 1.—*Percentage of stem-rust infection on parental strains of wheat and on segregates which gave infection reactions ranging from fully susceptible (S) to fully resistant (R). Also the percentage of leaf-rust infection of segregates grouped according to their reaction to stem rust*

Parents or segregates	Susceptible reaction (S)	Semi-resistant reaction (SR)	Segregating for S and SR	Segregating for SR and R	Resistant reactions (R)
Federation					
Stem rust	60				
Leaf rust	60s				
Sevier No. 59					
Stem rust		50			
Leaf rust		75s			
Federation×Sevier No. 59					
Stem rust					
No. of segregates	12	7	4	2	1
Range in infection	30–70	30–60	50–60	30–50	
Mean	58	49	55	40	15
Leaf rust	60–90s	70–85s	75–85s	75–85s	90

Table 1 establishes a segregation for resistance types of reaction to stem rust. By the F_5 generation 12 of 26 strains were homozygous for full susceptibility (S); 7 were homozygous for semiresistance (SR); and 1 for complete resistance (R). Six of the 26 strains were still segregating for rust reaction. Four strains segregated in 1928 (F_5) for complete susceptibility (S) and semiresistance (SR); two strains segregated for semiresistance (SR) and resistance (R). One of these gave a reading of 30 R-SR.

Observations also were made on leaf rust, but all the segregates studied were susceptible (S). The segregate resistant to stem rust was highly susceptible to leaf rust, the reading being 90s. The two strains segregating for resistance and semiresistance to stem rust gave readings for leaf rust of 85s and 75s when the readings for stem rust were 30R-SR and 50R-SR, respectively. With every leaf-rust reading higher than 60s, the data available do not show whether there is linkage between the reaction for stem rust and leaf rust as Hayes, Aamodt, and Stevenson[3] thought.

However, it is clear that out of 26 strains, three were more resistant than either parent. One of these was homozygous for a high type of resistance (15R).

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THE EFFECT OF LAND PLASTER APPLIED AS A DUST ON SEED CORN

E. N. Bressman

In recent years there has developed no little interest in the use of dust fungicides on seed corn. Most of the commercial dusts are organic mercury compounds and are used primarily to control disease and stimulate the growth of corn. Early in the spring of 1926 the writer's attention was called to the use of land plaster (powdered gypsum), as a dust on seed corn, by a grower in Western Oregon. Land plaster has long been used and known as a crop stimulant, but its use as a dust on seed corn for the control of mold fungi which seem detrimental to germination and to seedling growth, is a rather new idea. It is commonly added to the soil in Western Oregon as a fertilizer for legumes.

Germinator trials were conducted. These showed that seed treated with land plaster germinate more quickly and develop a larger and more vigorous root system than untreated seed. Figure 1 shows treated and untreated

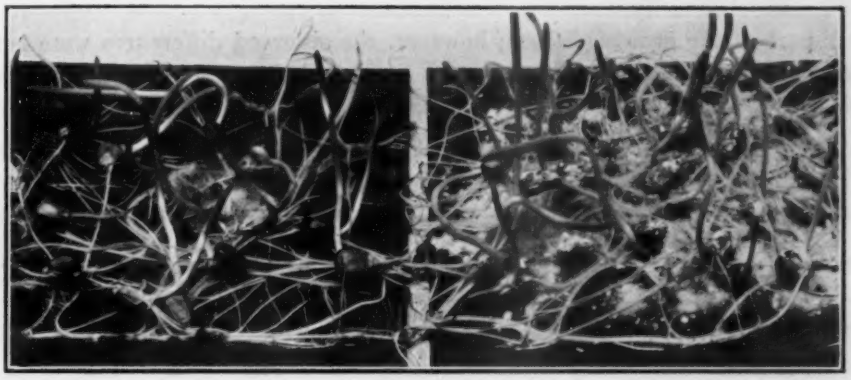

Fig. 1. Seed corn after 5 days in a standard germinator. Untreated (left) and treated (right).

Minnesota No. 13 seed corn five days after it was placed in the germinator.

In the field trials 8 pounds of commercial land plaster per acre were used. The corn was planted in hills at the rate of 5 kernels per hill and land plaster was dusted on the seed by hand before the hills were covered. After the corn had attained a height of about 5 inches, it was thinned to 3 plants per hill. The hills were spaced 3 feet, 4 inches apart each way. The plots were 1/35-acre in size. Only single plots were grown in 1926 and 1928. Duplicate plots were grown in 1927. For silage yields the entire plot was

harvested and weighed. The ears were then husked from this silage corn and weighed. In each of the three annual trials the larger growth and darker green color of the treated plots could easily be seen throughout most of the growing season. Figure 2 shows the plots in 1927. During the lat-

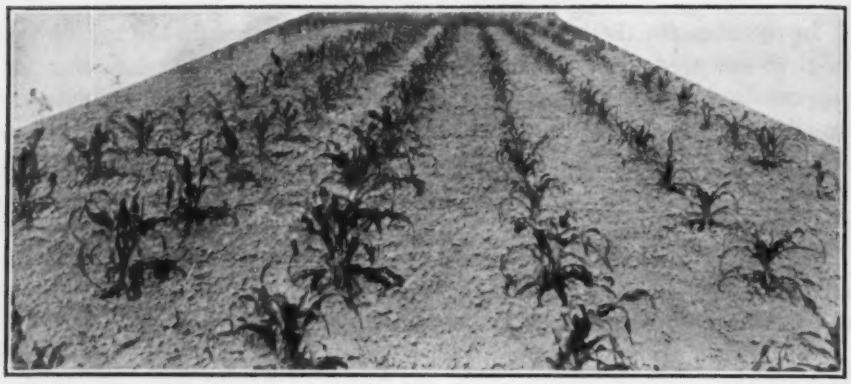

FIG. 2. The three rows of corn at the left are from seed treated with land plaster. The three rows at the right received no treatment. Corvallis, Oregon, 1927.

ter part of the growing season, however, the observed differences were not great. The following table gives the results of three annual trials in the field.

TABLE 1.—*The effect of land plaster on yields of Minnesota No. 13 corn at Corvallis, Oregon. Yields given in bushels of ear corn and tons of silage per acre*

	1926		1927		1928		Average	
Treatment	Bu.	Tons	Bu.	Tons	Bu.	Tons	Bu.	Tons
Land plaster on seed	61.0	6.5	58.5	6.2	48.0	5.5	55.8	6.1
No treatment	54.3	6.7	50.0	5.9	34.5	5.2	46.3	5.9

Several other dust treatments were used at various times in these experiments. Copper carbonate, Semesan Jr., and Uspulun gave slightly increased yields. Bayer's dust, Trockenbeize Höchst, Bayer's Compound, and Bayer's Spec. No. 169 gave decreased yields. All of the above dusts, used in excess, injured the germination of the seed. Land-plastered seed gave higher yields than that treated with any other dust.

Various amounts of land plaster, from one to nearly fifty pounds per acre, were used in additional trials. Stimulation of growth was obtained in all trials and no injury resulted. In addition to stimulating the growth

of corn, the land plaster eliminates some of the molds which are usually found in the germinator. Other molds are not controlled.

Land plaster does not readily adhere to the seed. A fertilizer attachment on the corn planter, which places the land plaster in contact with the seed in the soil, is the best means of application.

AGRICULTURAL EXPERIMENT STATION,
OREGON STATE AGRICULTURAL COLLEGE,
CORVALLIS, OREGON.

REPORT OF THE THIRTEENTH ANNUAL MEETING OF THE PACIFIC DIVISION OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

OFFICERS

President ..... J. W. HOTSON, University of Washington, Seattle.
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The meetings of the Pacific Division of the American Phytopathological Society were held in conjunction with those of the Pacific Division of the American Association for the Advancement of Science and Affiliated Societies at the University of California at Berkeley, June 19–22, 1929.

A short business meeting preceded the presentation of papers. In conformance with the requirements of the constitution, an amendment to the latter which provides for the automatic elimination of members whose dues are in arrears for two years, was passed by a unanimous vote of all members present.

The very excellent paper of Dr. Ruth F. Allen, a brief abstract of which accompanies the present report, was considered the most outstanding piece of research work presented before the society this year, from the standpoint of completeness as well as for its far-reaching importance. Because the paper conforms very closely to the requirements laid down by the Committee on Awards of the Pacific Division of the American Association for the Advancement of Science, the society has submitted Dr. Allen's paper to the committee in competition for the annual prize.

During the meetings moving picture films of members of the American Phytopathological Society were shown. These same films, which were shown at the annual meetings of the parent society in New York last winter, proved a source of much amusement and pleasure at the meetings of the Pacific Division.

There was an average attendance of forty at the Berkeley meetings, and thirty papers were presented, abstracts of which follow.

B. A. RUDOLPH, *Secretary-Treasurer.*

ABSTRACTS

Phoma terrestria, n. sp., as the cause of pink root of onions.—H. N. HANSEN.

The pink root disease of onions has for many years been attributed to species of Fusarium, *i.e., Fusarium malli* Taub., *Fusarium cromyopthoron* Sideris and other species. The writer was unable to produce this disease with these and other species of Fusarium

under controlled conditions. He did, however, readily produce the disease with a species of Phoma which he isolated from infected onion roots obtained from various localities in California and Texas. The name **Phoma terrestria**, n. sp., is suggested for this fungus.

The relative resistance of varieties and species of Citrus to bark diseases.—L. J. KLOTZ and H. S. FAWCETT.

Results of inoculation experiments with *Phytophthora* (Pythiacystis) *citrophthora* into 78 varieties and species of Citrus have confirmed previous observations and extended the information regarding many not previously observed. A method to secure uniform inoculations was worked out. The area of bark killed used as a measure of susceptibility.

The varieties and strains of lemon were all very susceptible. Sour oranges were very resistant. Commercial varieties of grape fruit and sweet oranges averaged as groups showed susceptibility about equal to each other but much less than lemon. As a group the pummelo varieties exhibited great variability, from a resistance only slightly less than that of the standard sour orange to a susceptibility approaching lemon. Variability in the sweet orange group was less than in the pummelo group. The mandarin was much below the pummelo or sweet orange, being similar in resistance to rough lemon and to the limes. The two varieties of citron inoculated showed pronounced resistance. The citranges—Sanford, Savage, and Cunningham—were resistant.

Experiments in the inhibition of the enzymes by the barks of the several varieties indicate the possibility of securing a biochemical test for resistance along the line indicated by Klotz in Science n.s. 66: 631–632. 1927.

On some limiting factors in the use of saturated petroleum oils as insecticides on living plants.—HUGH KNIGHT, JOSEPH C. CHAMBERLIN, AND CHAS. D. SAMUELS.

The scalecidally effective, but chemically inactive, saturated petroleum oils of viscosity 75–110 seconds Saybolt, recently employed successfully in competition with HCN fumigation for control of the red and black scales of Citrus in California, have been studied from the standpoint of dynamic phytotoxicopathy.

It was experimentally ascertained that these oils initiated metabolic disturbances which were reflected in decreased rates of transpiration, photosynthesis, downward carbohydrate translocation and in an increased rate of respiration. These effects, as well as rate of recovery, are positively correlated with and proportional to the viscosity of the oil. Phytometabolic normalization was found to be dependent upon oil elimination. Initial disappearance from the epidermis of the leaf results from intercellular absorption, the rate being a function of oil viscosity and epidermal and vascular morphology. *Intracellular* absorption next occurs followed by translocation *via* the phloem and medullary rays to apparently permanent storage in cells of the pith and old xylem. Oil translocation is a lengthy process and for more viscous types probably is never complete, thus serving to maintain a chronic condition of metabolic instability or abnormality.

The employment of oils of 60 seconds viscosity or less for practical scale control is strongly indicated.

Life history of Sclerotinia sclerotiorum (Lib.) Mass., in connection with the green rot of apricots.—RALPH E. SMITH.

This is a rotting of the young fruit of the apricot caused by the fungus mentioned, which, in seasons of favorable weather conditions, causes infection through the old calyces clinging to the surface of the fruit. No spore form of the fungus is known to occur on the tree. Its distribution depends on ascospores produced in apothecia from

sclerotia in the soil. The common idea has been that wet weather favoring fruit infection likewise induces ascospore production in orchard soil beneath the trees.

The dry, cold winter and early spring of 1929 were very unfavorable to this disease. Not a single case of green rot was observed and neither apothecia nor mycelium was found after observations were commenced on March first. Blossoms and young fruits of apricots and other fruit trees from many different places, various wild flowers, and other vegetation were collected at weekly intervals and placed in moist chambers. Apricot blossoms were just beginning to open when this was started. By this method it was found that *Sclerotinia sclerotiorum* was universally present on all sorts of vegetation in central, interior California between March 1 and May 1. No imperfect stage of the fungus was found except the occasional production of germinable gonidia. It would appear that ascospores or some other reproductive form of the fungus had been produced and widely distributed at some time before the observations were first made.

Influence of spindle-tuber disease on the physiology of the potato tuber.—WALTER JONES and T. E. RAWLINS.

Most living tissues of healthy tubers were found more highly resistant to the passage of an electric current than were similar tissues of diseased tubers. The difference in resistance is apparently insufficient to warrant the use of the resistance method by the grower for separating diseased from healthy tubers.

Juice from healthy tubers was found to have a higher resistance than from diseased tubers, indicating a higher concentration of electrolytes in the latter.

No distinct difference was found in the dry weight of ash content of diseased and healthy tubers.

Mass action in relation to infection with special reference to curly top of sugar beets.—EUBANKS CARSNER and C. F. LACKEY.

The fact that the quantity of the inoculum or dosage of the causal agent is generally one of the determining factors in infection is brought out by a review of the limited amount of literature dealing directly with this subject and by reinterpretation of pertinent data taken from a wide range of sources. The principle involved in this relationship is essentially the same as that manifested in the phenomena called allelocatalysis, spore-load effect, and synergistic or communal activity. The term mass action is preferred because, according to the hypothesis here advanced, the result of an inoculation, that is to say, infection or noninfection and usually the length of incubation period, depends, so far as it is determined by mass action, on the proportions of the chemical substances actively entering into the reaction.

The relation of mass action to infection is shown to hold in curly top as follows: (1) By varying the amount of inoculated virus by (a) inoculations with contrasting numbers of leaf hoppers and (b) unequal periods of exposure; (2) by use of plants differing in susceptibility; (3) by studies on the incubation of the virus in the insect; and (4) by comparing the minimal infective doses of the virus in its virulent and attenuated conditions.

The demonstration of mass action as a factor in curly-top infection makes clearer the significance of the observed relationship between time of planting and extent of damage in sugar-beet fields. It supports the claim that the amount of damage is positively correlated with the number of invading leaf hoppers. The feasibility of controlling the amount of virus renders the mass-action factor useful as a rough measure of curly-top resistance. It is argued that the demonstration of the relation of mass action to infection in curly top supports the theory that the virus is some sort of living organism.

Discovery of the perfect stage of a Phomopsis on lemon bark.—H. S. FAWCETT and C. L. SHEAR.

A Diaporthe was discovered on the bark of lemon trees affected with decorticosis at North Whittier Heights in March, 1928. (Ann. Rept. Calif. Agr. Exp. Sta. 1927–1928, p. 42.) Pure-culture tests and inoculations have shown it to be the perfect stage of *Phomopsis californica* Faw., which had previously been described as the causal agent of decorticosis of lemon trunks and stem-end rot of lemon fruits (Phytopath. 12: 419–424, 1922). The perithecia are embedded in the surface layers of the dead flakes or scales of bark.

Occurrence and insect transmission of Nematospora in California.—HOWARD S. FAWCETT.

The substance of this paper has appeared in Phytopathology 19: 479–482, in which a note by Gardner (Phytopath. 14: 31) on Nematospora in Lima beans was overlooked. *Nematospora Coryli* was discovered in pomegranate and Citrus fruits and in cotton bolls in Imperial County, California, in the fall of 1928. It was found widely distributed within the Imperial Valley on cotton bolls. Experiments have confirmed the first observations indicating that the fungus was being carried by the Western leaf-footed plant bug, *Leptoglossus zonatus*, from pomegranate to Citrus fruits. Pomegranate appeared to be a new host for Nematospora and *Leptoglossus zonatus*, a new carrier. Pure cultures on glucose-potato agar are yeast-like, resembling in growth that described by Ashby and Nowell (Ann. Bot. 40: 69–83, 1926). The fungus produces in pomegranates depressed spots in the fleshy covering of the seeds followed by browning and collapse of the pulp, in Citrus brown or reddish brown stains and drying out of juice sacs with premature coloring and dropping, and in cotton bolls yellow or reddish brown discoloration of the lint and seeds.

Descriptions and illustrations of injury to cotton bolls in previous entomological literature indicate strongly that the fungus has been present for a long time in Imperial Valley and possibly in Arizona and Northern Mexico.

A preliminary report of a digest of the world's literature on hadromycosis due to Verticillium spp.—B. A. RUDOLPH.

Verticillium hadromycosis is a disease to which a great group of the most widely unrelated dicotyledonous plants are susceptible. The literature on the subject is in a very chaotic condition. New hosts are being reported constantly. The host indices and bibliographies which have appeared are very incomplete and unsatisfactory. A bibliography and a digest of the literature up to and including 1928 have been prepared. A host index which is based upon authentic records includes one hundred and forty distinct species distributed in thirty-five families and eighteen orders. The history of the disease in each species has been given briefly. It is hoped that such a paper, soon to be ready for publication, will be helpful to professional plant pathologists.

Leaf and scape spot of the Amarillidaceae in California.—C. O. SMITH.

The cause of this trouble is *Phyllosticta narcissi* Anderh. It causes red spots on Amaryllis (Hippeastrum) and dead areas followed by yellowing on Narcissus. This organism has been isolated from each of these hosts and successful inoculations and cross inoculations have been made. In this study a different form resembling *Stagonosporium curtisii* (Berk.) Sacc. was found. A study of this form and *Phyllosticta narcissi* indicates that the two are probably identical. When puncture inoculations on Narcissus and Amaryllis are made with *Phyllosticta narcissi* the pycnidia often contain spores that are variable in size, shape, and septation. A single pycnidium may have large 1–3 septate spores and small continuous ones, as shown by the following:

1-cell spores measure	4.5–10 x 3 –4.5 μ
2-cell spores measure	8–13 x 5 – 6 μ
3-cell spores measure	12–18 x 4.5– 6 μ

In dilution plates from these septate spores seven subcultures have been studied and from them successful artificial inoculations have been made. All of these subcultures on sterilized Narcissus stems show the Phyllosticta type of fruiting.

It is believed that the size and septation of these spores may be a stage of maturity just preceding spore germination induced by certain favorable conditions. The larger Stagonosporium-like spores germinate within 3 to 4 hours, while the small continuous spores require 7 to 9 hours.

The Stagonosporium form appears on tissue inoculated with *Phyllosticta narcissi* from Amaryllis and Narcissus. Cultures made from the Stagonosporium fungus will again develop the Phyllosticta type. They are evidently different forms of the same fungus.

Diamond canker of the prune.—RALPH E. SMITH.

This disease of the French prune causes a pronounced roughening and swelling of the bark on the trunk and main limbs. The disease develops very slowly and gradually; in its early stages the quantity and size of the fruit are actually increased but eventually the tree becomes stunted and dies. The canker originates in the phellogen and consists mainly of a thick, leathery, heavily suberized mass of cork cells, much like the normal outer bark of many trees.

The disease has been observed only on the French prune and the variety Standard. There is considerable evidence that the Imperial, Sugar, and Robe de Sergeant prunes, other plums, and the almond, peach, and apricot are immune from diamond canker.

This condition has been thought to represent either a distinct strain or a systemic disease of the French prune, intentionally propagated and distributed by a certain nursery because of the increased size of the fruit. Investigation reveals little to support this idea but rather points to the conclusion that the disease is caused by a slow-acting fungous or bacterial infection initiated where callus formation is taking place, *i.e.*, wounds, bark cracks, or pruning cuts. Cultures and inoculations do not readily reveal the cause of the disease which in many ways resembles the so-called scaly bark (psorosis) of citrus trees. A fungus resembling *Dematium pullulans* d. By. is very regularly isolated from the cankers, together with a species of Actinomyces and a small Bacillus.

Resistance to Septoria tritici in wheat.—W. W. MACKIE.

Septoria tritici Desm. causes what is commonly called speckled blotch because of the prominent black pycnidia usually characteristic of the mature lesions. It is distinguished from glume blotch (*Septoria nodorum* Berk.) because its attacks are confined solely to the leaves. The disease is common in northern California and, in wet years throughout the State. It is especially prevalent in late wet spring seasons. It survives in the old diseased straw in the form of pycniospores in the old pycnidia. These spores are distributed by the wind and scattered upon young wheat seedlings by the first rains. A generation from spore (pycniospore or conidiospores) to spore requires from 12 to 15 days. Young seedlings are severely attacked and many killed. Under favorable conditions the disease continues until the dough stage, weakening the plants and causing them to lodge. The grain is shriveled. Tests with many hundreds of varieties yielded no immune varieties in the common bread wheats (*Triticum vulgare*) but many in the other species of wheat. By repeatedly crossing the most resistant selections of hybrid stocks, Septoria-free plants were produced. These in turn were crossed with susceptible

plants in F_1, and three susceptible to one resistant in F_2. In F_3 278 families (plant to row test) gave a very close approximation to a 3:1 ratio of susceptibility to resistance.

Tuber transmission of psyllid yellows in California.—MICHAEL SHAPOVALOV.

Although the tomato psylla (*Paratrioza cockerelli* Sulc.) has long been known to exist in California, psyllid yellows on potatoes was not discovered until the fall of 1928. At that time some badly diseased fields were found and several young tubers collected and planted out-of-doors and in pots at Riverside. One mixed lot, taken from different hills in a severely-attacked field, produced plants in part affected by yellows; some also showed mosaic symptoms, and part were free from this disease. Another lot, the progenies of several hills kept separately, showed different stages of the disease in plants grown from tubers of different hills. Furthermore, it was observed in the spring of 1928 that fields planted with potatoes grown in the psyllid-infested area showed a considerable amount of the disease in the absence of psyllids. The symptoms, however, were very much more pronounced in dry and hot interior sections than on the Coast or when artificially shaded. These data indicate: (1) At least in some localities psyllid yellows may be transmitted with the tubers; (2) the progeny may show various stages of the disease; and (3) psyllid yellows and mosaic have distinct and specific effects when present in the same plant.

Pythiaceous root parasites of various agricultural plants.—C. P. SIDERIS.

These studies on the pathogenicity of different pythiaceous organisms on various agricultural plants were conducted to determine the pathogenic population of a soil by means of some very susceptible plant ("indicator plant") and to ascertain the contribution of other plants, through their susceptibility or resistance, to the increase or decrease of such a population.

The organisms used for the inoculation of the various plants had been mostly isolated from pineapples, and in few cases from such plants as spinach, snapdragon, *Carica papaya*, and castor bean. The pythiaceous organisms numbered nine species of Nematosporangium, ten of Pythium, five of Phytophthora, and one sterile Phycomycete. The hosts were planted in sterile soil in root-observation boxes. When their roots were about three to four inches long they were inoculated with pure cultures of the different fungi. The susceptibility of the various hosts was as follows: Dicotyledonous plants such as *Canavalia ensiformis* (Jack bean), *Vigna sinensis* (cowpea), *Phaseolus aureus* (Mung bean), *Vicia faba*, *Cajanus indicus*, *Helianthus annus*, *Ipomoea batatas*, *Solanum tuberosum*, and *Ricinus communis*, were susceptible to most species of Pythium and some slightly to Nematosporangium; whereas, such monocotyledonous plants as *Pennisetum barbinode*, *Saccharum officinarium*, *Zea mays*, *Triticum vulgare*, and *Ananas sativus* were found susceptible only to the species of Nematosporangium. Onion plants have been found very resistant to all species of Nematosporangium and Pythium, but very susceptible to all five species of Phytophthora.

Studies on the nature of host resistance to Armillaria mellea.—HAROLD E. THOMAS.

The mode of entrance and subsequent development of *Armillaria mellea* in various susceptible and resistant roots and tubers, including *Juglans regia*, *Prunus persica*, *Prunus cerasifera*, *Pyrus communis*, *Daucus carota*, *Pastinaca sativa*, *Dahlia* sp., and *Solanum tuberosum*, have been investigated.

Invasion of the root is accomplished by direct penetration of a branch of the parent rhizomorph through the sound healthy cork layer of the host. The method is similar in the several hosts investigated with no apparent difference between susceptible and resistant ones. The branch penetrates as a unit and was never observed to send

out single hyphae into the root ahead of it. In susceptible roots, after gaining entrance, rhizomorphs grow rather rapidly and cause general destruction of the host tissue. In resistant roots the fungus readily gains entrance but is ordinarily unable to establish itself. It destroys but little of the attacked root. The wounds thus formed soon cork out or heal over.

The fungus grows well on the expressed sap of certain roots and not at all or only very poorly on others, but there appears to be little correlation between the inhibition of growth and the resistance of the host.

Structural or morphological differences of the host probably exert little influence on resistance, which appears to be of the nature of a vital, antagonistic interaction between host and parasite.

Inheritance of resistance to barley scald.—W. W. MACKIE.

Barley scald is caused by *Rhynchosporium secalis* (Heinsen) Davis. The fungus survives in the soil and in diseased plant material. The spore, falling upon the leaf, germinates and pushes out hyphae which form appressoria in the stomata. Large lesions with white centers soon appear, hence the name "scald." Several generations occur during the growing season, October to March. Late-sown grain escapes attack; early-sown grain usually suffers severely. Few resistant and no immune varieties were found. Repeated crossing of highly-resistant varieties produced highly-resistant and scald-free plants under heavy attack. By crossing scald-free plants with highly-susceptible plants the following Mendelian ratios were secured for 523 F_3 families at Davis:

Scald resistance in F_3 families of hybrid barley

	Homozygous resistant	Heterozygous susceptible and homozygous susceptible
Observed	126.00	397.00
Expected	130.75	392.25
Deviation	−4.75	−4.75
Probable error	5.82	5.82
D/PE	.82	.81

The homozygous-resistant families were easily separated, for resistance is recessive. The heterozygous-susceptible and homozygous-susceptible families were difficult to separate owing to the presence of other leaf-attacking fungus diseases including mildew, spot blotch, rusty blotch, and stripe. The results indicate a 3:1 ratio of susceptibility to resistance due to a single factor for resistance.

Further studies of the modification of sugar-beet curly-top virus by its various hosts.—C. F. LACKEY.

Further investigations on attenuation of the curly-top virus by various hosts show that other wild and cultivated hosts attenuate the virus in a manner similar to that recorded in previous reports. The meaning of attenuation as here treated is the lessening of the virulence or infection power and the development of severe symptoms. In addition to the virus-attenuating plants previously reported, the following hosts have been shown to exercise this effect on it: Lamb's quarter, *Chenopodium album* and *C. album viride*; tomato, *Lycopersicon esculentum*; peasant's tobacco, *Nicotiana rustica*; hubbard squash, *Cucurbita maxima*; watermelon, *Citrullus vulgaris*; spinach, *Spinacia*

oleracea, and resistant sugar beets, *Beta vulgaris*. Fragmentary evidence indicates that Russian thistle, *Salsola kali tenuifolia*, *Kochia scoparia*, and beans, *Phaseolus vulgaris* also attenuate it. In experimental tests the mild symptoms on the sugar beets to which the attenuated virus was transferred, as well as a reduction in percentage of infection, demonstrated that the virus had been attenuated.

Several preliminary tests gave evidence that chickweed, *Stellaria media*, very susceptible to curly top, can, under certain conditions, reactivate the attenuated virus almost to its original virulence.

Hydrogen-ion concentration studies on Penicillium italicum and P. digitatum.—RAIMUND H. MARLOTH.

In the course of an investigation of the effect of sodium bicarbonate on *Penicillium italicum* and *P. digitatum*, both molds of citrus fruits, the latter being almost specific, their behavior with regard to the hydrogen-ion concentration of their media has been such as to warrant this preliminary report.

All the media used had sucrose as a source of carbohydrate. In utilizing the sucrose, the fungi produced oxalic acid, because of an incomplete respiratory process. As a consequence, the pH of the media was lowered, the degree of lowering being dependent on the buffer system. Not being a germination factor, it was found that spores of *P. italicum* showed a small percentage of germination at pH 1.9, while those of *P. digitatum* did not germinate below pH 2.3. The optimum range of pH for the former fungus for the modified Duggar's Solution was 3.0 to 7.0 and 3.5 to 8.0 for the latter.

Using the apparatus described by the writer in *Science* (LXIX No. 1794) the fungi were grown for nine days on a well-buffered medium, potassium citrate being used as buffer and the pH being kept constant by daily renewal of the solution. At the lowest growth limits, 2.0 for *P. italicum* and 2.4 for *P. digitatum*, no spores formed and the mats were fragmentary and brittle. At the neutral point and above, the mats were somewhat slimy, and those of the latter fungus formed below the surface of the solution. The optimum pH range for growth, as determined by the dry weight of the mats, was 3.0 to 5.5 for the latter and 2.5 to 6.7 for the former fungus. These ranges are subject to slight extension on the upper limit. The point brought out by these few results is the marked difference in the physiology of these two morphologically closely-related fungi. The rate of growth of the mat, as measured by the rate of oxalic acid formation, is constant once the young mat has covered the surface of the solution, and the amount of increase in weight of the mats per day, growing at different hydrogen-ion concentrations within the optimum range, is virtually the same.

Taxonomic studies in the family Pythiaceae.—C. P. SIDERIS.

The genera Nematosporangium, Pythium, and Phytophthora are differentiated by the differences in their zoospore-producing organs. There are three morphologically different organs, the prosporangium, emission collar, and zoosporangium. The prosporangium is a reservoir of the protoplasm for the development of zoospores; the zoosporangium, for the full development and discharge of zoospores. Separating the prosporangium from the zoosporangium is the emission collar through which the protoplasm passes. The wall of the prosporangium is continuous and identical with the exterior wall of the hypha supporting this organ; whereas, that of the zoosporangium is not, but constitutes a part of the so-called ectoplast or protoplasmic membrane of the prosporangium. The zoosporangium is of short duration; it emerges from the emission collar almost simultaneously with the flowing protoplasmic contents of the prosporan-

gium and lasts until the zoospores are completely formed and have escaped in the surrounding medium.

The different genera may be differentiated on this basis, as follows:

Nematosporangium: Prosporangia not well defined, nematoid, alantoid, or rarely subspherical, intra- and extra-marginal; emission collar very long; zoosporangia spherical, size variable; zoospores few to many.

Pythium: Prosporangia well defined, spherical to ovoid, mostly extra-marginal, rarely intra-marginal; emission collar short; zoosporangia spherical, size variable; zoospores few to many.

Phytophthora: Prosporangia well defined, lemon-shape to spherical, mostly extra-marginal of different sizes; zoosporangia developing within the walls of prosporangia; emission collar entirely lacking or rarely slightly developed; zoospores few to many.

Species of the genus Nematosporangium are differentiated by their rapid or slow production of oospores in culture media and tissues of hosts, by the filling or not filling of the oogonium by the oospore, and by other characters.

The species of the genus Pythium comprise four sections: (1) Those reproducing asexually, *i.e.*, zoospores and conidia; (2) those reproducing sexually, *i.e.*, oospores and conidia; (3) those reproducing sexually and asexually; and (4) those reproducing by means of conidia alone. The new sections proposed are, respectively, Zoosporium, Oosporium, Amphisporium, and Conidiosporium.

A similar subdivision of the genus Phytophthora is proposed.

A filterable microorganism from Eutettix tenellus and the sugar beet, both infected with curly top.—OLIVE SWEZY and HENRY H. P. SEVERIN.

Rickettsia-like microorganisms were found to be a common inhabitant of the intestinal tract of *Eutettix tenellus* (Baker), the carrier of curly top of sugar beets. When the insects were macerated in a suitable culture medium and passed through fine (W) Berkefeld filters, similar organisms appeared by the second or third day in the cultures made from the filtrate. No organisms have been found associated with this disease in the sugar beet. When the juice from macerated beets was passed through fine (W) Berkefeld filters and cultures made from the filtrate, organisms were obtained similar to those in the cultures from the insect. Slides were made in both cases from the filtrate immediately on passing the filter. These were fixed and stained by the same methods used with slides from the cultures but these showed no visible organisms. Cultures made from the noninfective beet leaf hopper and sugar beets gave negative results in all cases, though the same culture media were used and identical processes followed throughout. It thus appears that the microorganisms present in the infective beet leaf hopper have a filterable stage in their life history and can not be obtained from cultures from the noninfective insect or from healthy sugar beets.

The toxicity of some commercial dusts to conidia of Bremia lactucae.—JAMES B. KENDRICK.

Laboratory studies were undertaken in the autumn of 1927 to determine the efficiency of some of the common commercial dusts in preventing the germination of conidia of *Bremia lactucae*. Five sulphur compounds (Kolodust, Koloform, Dry Mix, Super Sulfodust, Powdered Sulphur) and four copper lime dusts (D-6, D-18, D-25, Copodust) were used in these tests. Conidia were secured from young lesions on lettuce leaves and a spore suspension was made in tap water. A drop of this suspension was placed on each of a series of sterile microscopic slides which had been previously dusted by means of small hand dusters. The slides were placed in Petri-dish moist chambers and held from 12–18 hours at temperatures ranging from 4°–25° C. Conidia germinated

by the production of a germ tube. The results showed that little if any toxic effect was exerted by the sulphur compounds, while in no case did germination take place in the presence of the copper-lime dusts.

Progress in the study of certain diseases of the avocado.—WM. T. HORNE.

The author has given attention to avocado diseases at the Citrus Experiment Station since July, 1928.

Carapace spot (new name) is suggested for certain large surface blemishes of mature fruit. Ordinarily, the quality of the flesh is not impaired. Preliminary evidence is given that the cause is desiccation or very slight surface abrasions. Very young fruit is involved. The study is being continued to determine particularly the effect of injuries received at different stages of development of the fruit. A parasitic etiology is not indicated.

End spots, the name given by Dr. Coit to a decline of extensive areas at the blossom end, apparently is a collapse associated with maturity and stress of climatic conditions. Neither citrus blast nor anthracnose seems ordinarily involved.

Sun blotch, apparently a chimera, is being studied with E. R. Parker, through grafting, and as to possible infectiousness.

Diseases concerned with salt relation in the soil are being studied by A. R. C. Haas, and the field aspects of his results are receiving attention. *Chlorosis, tip burn*, and *little leaf* apparently are comparable with these diseases in Citrus.

Studies of a large collection of fungi and bacteria isolated by C. C. Lindegren and H. S. Fawcett are not yet ready for report.

Further studies on Penicillia of citrus.—L. J. KLOTZ.

Histological study of citrus fruit decayed by *Penicillium digitatum* and *P. italicum* has thus far revealed no microscopic differences in the methods of attack by these organisms. The hyphae were tortuous, ramifying, ranging from 3 μ to 17 μ in thickness, distinctly intracellular as well as intercellular, and without definite haustoria; some hyphae showed very apparent constrictions at points of wall penetration. The fungi penetrated all cells of the albedo, flavedo, and core and the cells of the oil glands, but avoided the space of the glands containing oil. With advancing decay juice vesicles became involved, first the stalk cells of the vesicles and finally those cells in the expanded, juice-bearing part showing hyphae. The aerial, spore-bearing hyphae arise from heavy-wall mycelium which collects substomatally and ruptures the epidermis. Advance in action, if present, could not be detected by isolation methods, but stained microscopic sections gave an indication of such action, the affected area having no mycelium extending more than .3 mm. beyond the region bearing hyphae. Preliminary observations indicated that diastase production by *P. italicum* increased with rising temperature up to 32° C., which is near the maximum for growth. Temperature had little effect on production of invertase in either fungus.

Observations on powdery mildew of raspberry in California.—LYSLE D. LEACH.

In the fall of 1928, while studying the life history of powdery mildew of raspberries in the Santa Clara Valley, abundant perithecial formation was observed on the Ranere variety. Perithecia were present on infected canes near the apex, leaves, leaf petioles, and flower buds. Preliminary morphological studies of the perithecia, reticulations, asci, and ascospores of the causal fungus agree closely with the descriptions given for *Sphaerotheca humuli* (DC.) Burr.

To determine if perennation of the mycelium within the buds, as has been reported from Minnesota, was the common method of overwintering in the Santa Clara Valley,

four plants and 192 cane tips which had previously shown severe mildew were transferred to the greenhouse in the dormant stage. Of the 969 shoots which subsequently developed, only one showed mildew. Field observations in the spring of 1929 showed that virtually all early infection was confined to the new growth produced from the roots during the current season. The predominating appearance of the diseases on the young shoots just out of the ground suggests that the perithecia on the debris around the base of the plants may be the common source of overwintered spores in this region.

Susceptibility of cowpea varieties and selections to Fusarium wilt and root knot.—JAMES B. KENDRICK.

Serious losses are annually incurred by cowpea growers in the San Joaquin Valley, California, from Fusarium wilt and root knot. In 1927, 74 plant selections were made in a field of Blackeye cowpeas in which 90 per cent of the plants were dead from wilt and root knot. These selections and 25 varieties of cowpeas were planted in a two-acre plot in this field in 1928. Thirty-two of the selections proved to be 100 per cent susceptible. The remaining 42 selections varied in susceptibility from 55 to 95 per cent. Thirty seemed to possess some resistance and seed was saved for further tests.

The following varieties showed no evidence of disease: Brabham, Catjang, Columbia, Conch, Early Black, Iron, and Virginia Blackeye. Susceptibility varied in the other varieties as follows: Taylor, Dixie Queen Browneye, Progressive White, Victor, Cream Crowder, and Large Blackeye from 2 to 15 per cent; Extra Early Blackeye, Potomac, Groit, and Gallavant from 30 to 50 per cent; Whippoorwill, Arlington, Ramshorn Blackeye, Early Buff, Wood's No. 11 Blackeye, Early Red, New Era, and White Queen from 60 to 100 per cent.

A severe case of aerial "crown gall" on hot-house roses.—J. T. BARRETT.

The aerial form of crown gall has been reported on several hosts including rose. An unusually abundant infection on the Golden Ophelia variety in a glass house near Oakland has been under observation since December, 1928. The plants were on their own roots, had been in the beds two summers, and were large, thrifty, and productive. Practically every plant of the more than three thousand bore aerial galls. These ranged in size from a few millimeters to three inches in diameter and could be found on stems of all sizes and even on leaf petioles. Many infections took place at the out ends of the stems after removal of the flowers. Inoculations with the isolated crown-gall organism, *Bacterium tumefaciens* S. & T., are developing galls. In May of this year the plants were removed from the beds and burned. As a whole the roots were clean and healthy. Only a very few showed any crown-gall infection. In contrast, the Russell variety in another house has no aerial galls but considerable infection on the crown. The Mensing, a variety said to be closely related to the Golden Ophelia, is developing considerable aerial gall at the present time. Overhead sprinkling probably spreads the organism. No satisfactory explanation can be offered at the present time for lack of root infection on the Golden Ophelia.

Pythiaceous root parasites of pineapples.—C. P. SIDERIS and G. E. PAXTON.

Microfloral isolations from the diseased roots of pineapples yielded eight species of Nematosporangium, five of Pythium, and two of Phytophthora. The most predominant were two species of Nematosporangium, the others having been isolated only a few times, except *Pythium splendens.*

A composite soil sample of about one-half cubic foot was taken from the area under investigation, placed in a root-study box, and planted to pineapple plants. The roots were examined daily and those that died were removed and planted in Carica papaya-agar media. All of the organisms thus isolated reproduced the disease upon reinoculation.

Histological studies show that the different species of Nematosporangium may be identified inside the tissues of the host by such morphological structures as prosporangia and oospores; some species produce the latter structures readily; others slowly, or never, depending on the amount and quality of food they can obtain from the tissues. The species of Pythium may be identified by the size and shape and the smooth or spiny surface of their oospores, also by the filling or nonfilling of the oogonium. Different species of Pythium produce hues of bluish green on the diseased area which may partly serve for their identification.

Pineapple root rots caused by species of Fusarium.—C. P. SIDERIS.

About 30 species of Fusarium have been isolated from diseased pineapple roots during investigations concerned with the pathogenes involved in the wilt disease of pineapples. Few of these have been employed for the inoculation of plants grown in sterile soil. In a few cases one of these organisms has been observed invading the water-conducting vessels and killing the tip of a few of the inoculated roots, but not all, to an extent of two inches. The organism is an extremely weak parasite. The roots that had been invaded by the organism were those surrounded by very wet soil, whereas, those that happened to be in drier areas resisted invasion.

Another species of Fusarium has been observed to attack the main root through tiny rootlets or lateral roots, the resistance of which probably is low. Once it has become established on dead superficial tissue it kills the root by means of toxins. The toxin-permeated tissue becomes brown with material resulting from the dead protoplasmic contents of the pineapple root cells. The fungus never has been found among the brown dead tissue, but spreads throughout after the brown material undergoes further chemical decomposition.

Stem rot of pineapple plants.—C. P. SIDERIS.

Three pythiaceous fungi have been found causing this disease, namely, *Phytophthora meadii* and *P. melongeae* and another of possibly a new but closely related genus. *P. meadii* has been isolated from diseased plants grown on the island of Oahu and *P. melongeae* on Lanai. The disease occurs more often during the winter and spring months. *P. meadii* has been found also to cause fruit rot and *P. melongeae* stem rot of Antirrhinum.

The undetermined organism shows morphological similarity to *Pythium splendens* and *Phytophthora parasitica*. Its spherical to subspherical conidia have never produced zoospores, nor have oospores ever been observed by means of which a definite identification could be established. This organism is very destructive to young pineapple plants during periods of high humidity and low (for Hawaii) temperatures, such as 60–70° F. It may cause stem rot or root rot.

The various organisms invade the stem through the basal tissues of tender leaves and cause a soft rot.

In the case of stem rot by *P. meadii* and *P. melongeae* spraying with some fungicide may prevent the further spread of the disease. With the undetermined organism a similar treatment is not very promising as the organism is capable of living in the soil and invading the stem through the roots.

Heterothallism in Puccinia graminis.—R. F. ALLEN.

A sporidium of *Puccinia graminis* on a barberry leaf germinates promptly, passes through the outer wall, and forms a 3- to 5-cell primary hypha in an epidermal cell. Branches from this pass down into intercellular spaces. The mycelium is haploid. About

the fourth day, hyphae grow up beneath the epidermis, initiating pycnium formation. Details of the development of the pycnium and its spores have been traced.

In isolated infections, structures resembling aecia form at the normal time and place, but they consist of haploid cells only, and after undergoing some expansion and the first differentiation into areas, the whole structure dies. Usually no spores form, but there is evidence that a few old haploid aecia develop spores irregularly.

After pycniospores of different infections have been mixed, fungous cells containing two or more nuclei can be found in the wall of the pycnium, in hyphae leading from it, in a few of the hyphae between pycnia and aecia, between older and younger aecia, and beyond the youngest. Diploid cells are scattered throughout the aecium at all stages of its development and, at the time of spore formation, the centrally located diploid cells develop, initiating spore chains directly. (Cooperative investigations by the College of Agriculture, University of California, and the Bureau of Plant Industry, N. S. Department of Agriculture.)

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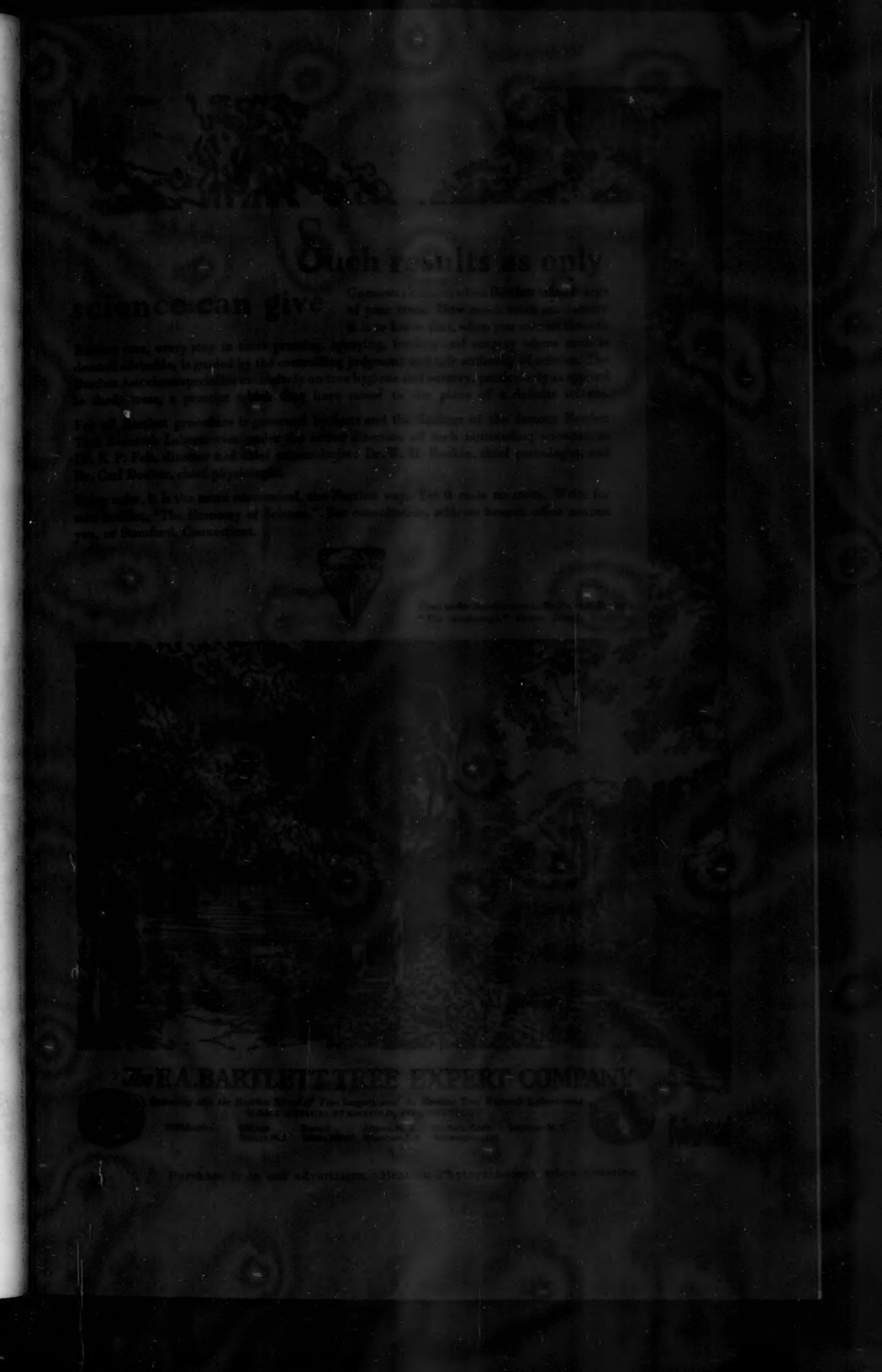

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